MECHANICAL ENGINEERING

INCLUDING THE ENGINEERING INDEX

THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS

The Lives of Engineers

Carlyle said that "the history of the world is the biography of great men." Written history contains few records of the lives of great engineers, although their influence upon the development of civilization has been tremendous. The publication of the life of an engineer is therefore a notable event. The Autobiography of John A. Brashear, Past-President of the A.S.M.E., will be issued during the coming month and it will be followed by the Life of John Edson Sweet, a Founder and Past-President of the Society. These volumes will be acclaimed as welcome additions to the meager record of the lives of American engineers.

SEPTEMBER 1924

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ADVERTISING

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E. F. DuBrul

N. W. Storer

D. H. Chason

G. S. Radford

C. E. Kerchner

L. D. Burlingame

Contributors to this Issue

N. W. Storer, author of the paper on Recent Developments in Electric Locomotives, and general engineer in the railway department of the Westinghouse Electric & Manufacturing Co. since 1904, is well known among railway engineers. He was graduated from Ohio State University in 1891 and shortly afterward entered the engineering department of the Westinghouse Co., where he has since remained. He was originally a designer of motors and generators, especially for railway service but he soon became responsible for the design and development of electric locomotives and car equipment. Since 1912 he has devoted himself to general problems of railway electrification and to new developments. He has thus been in touch with electric-railway problems since 1891 and intimately associated with both the development of the a.c. and the d.c. railways systems.

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L. D. Burlingame, who writes on Standardization Versus Individuality, is industrial superintendent and patent specialist for the Brown & Sharpe Manufacturing Co., Providence, R. I. He was educated in the public schools of Providence and served his apprenticeship in the drafting room and machine shop of the Browne & Sharpe Co., working as a draftsman until 1888, when he was appointed chief draftsman, a position he held for twenty-five years.

Mr. Burlingame is chairman of the Sectional Committee on the Standardization and Unification of Screw Threads, of which the A.S.M.E. and the S.A.E. are sponsors, and vice-chairman of the Committee on Tolerances and Allowances for Machine Fits in Interchangeable Manufacture.

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D. H. Chason, methods, equipment and experimental engineer with the Singer Manufacturing Co. since 1913, is the author of the paper in this issue on Comparative Methods of Tool Design. Mr. Chason served his apprenticeship as tool and die maker and has been associated with a number of firms in that capacity as well as an experimenter—firms including the General Electric, Westinghouse, Mergenthaler Linotype, Underwood Computing Machine and National Cash Register companies. During the war he was in charge of all the gage work in connection with the Singer company's contract for manufacturing recoil mechanisms for the French "75" field gun.

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Earle Buckingham, engineer with the Pratt & Whitney Co., Hartford, Conn., is the author of the paper on Shop Measurements. Mr. Buckingham was born in Bridgeport, Conn., and was educated in the schools there, later attending for two years, 1904–1906, the United States Naval Academy. During his career he has been associated as draftsman with the American Graphophone Co., the Veeder Manufacturing Co., and the Royal Typewriter Co. During the war he served as captain in the engineering division of the Ordnance Department of the Army.

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E. F. DuBrul, general manager of the National Machine Tool Builders' Association, Cleveland, Ohio, contributes an article on Forecasting Demand for Industrial Equipment. Mr. DuBrul holds the degrees of B.S., A.B., L.L.B. and A.M. from Notre Dame University, Ind. He was associated for a number of years as secretary and as vice-president with the Miller, DuBrul and Peters Manufacturing Co., Cincinnati, manufacturers of cigar and cigarette machinery. Later he became president of the Pyro Clay Products Co., also of Cincinnati. Since 1921 Mr. DuBrul has been with the National Machine Tool Builders' Association.

G. S. Radford, who contributes to this issue an article on Measurement of the Quality of Product, was graduated from the United States Military Academy in 1903. He then entered Massachusetts Institute of Technology where in 1905 he received the degree of M.S. Until 1915 he was an officer in the U. S. Corps of Naval Instructors. In 1915 Mr. Radford resigned from this position to join Brigadier-General John T. Thompson (retired) on the staff of the Remington Arms Co. Two years later he became manager of the contract division of the U. S. Shipping Board E. F. C. He resigned in 1918 to enter the consulting field.

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C. E. Kerchner, whose paper on Lignite Distillate appears in this issue, is an instructor in mechanical engineering in the University of North Dakota. He is a graduate of Pennsylvania State College, receiving his B.S. in mechanical engineering in 1918. He served overseas during the war and upon his return entered the combustion-engineering department of the Bethlehem Steel Corporation. Since 1912 he has been at the University of North Dakota where he has charge of the mechanical-laboratory work and assists with the courses in theory and design.

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W. H. Aldrich, presents a paper in this issue on Pulverized Fuel at the Cleveland Electric Illuminating Company's Lake Shore Plant. Mr. Aldrich is superintendent of the plant in question.

Machine-Tool Convention

New Haven, Conn., September 15–18, 1924

The A.S.M.E. Machine-Shop Practice Division and sixteen of the eastern Local Sections of the Society are cooperating to make the fourth combined machine-shop exhibit and technical meeting national in scope. The exhibit is to be held in Mason Mechanical Laboratory, an ideal spot for the display of typical examples of our modern machines.

The technical program embraces technical papers, round-table discussions, committee meetings, plant visits, motion pictures of industrial processes, etc. Four of the papers to be presented at the meeting are published in this issue, those by Messrs. Burlingame, Buckingham, Chason, and DuBrul.

For a more detailed account of the program for these three days in September, see the A.S.M.E. NEWS for August 7.

MECHANICAL ENGINEERING

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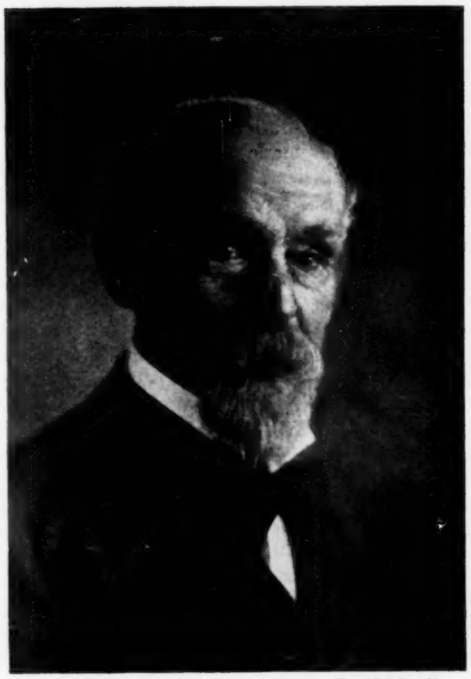
"He Loved the Stars"

Excerpts from the Autobiography of John A. Brashear, Past-President, A.S.M.E., Which Contains Great Inspiration for Engineers and Scientists

"'WHAT man is there among us who, coming in contact with a great soul, is not made the wiser, better and happier thereby. A drop of water on the petal of a lotus glitters with the lustre of a pearl.'

"Who of us will ever forget the cordial greetings, the delightful talks he has given us, the cheery smile on his face as he has told us of his life work; aye, such men as Uncle John 'help to move this dark world nearer the sun.' They fail not to pour good oil on the axis of this old round earth that she may run smoother on her bearings as we journey around the sun. It is such men that

'Give us the glad good morning
As we pass along the way,
And leave the morning's glory
Over the livelong day.' "



Zweifel Studio

JOHN ALFRED BRASHEAR

The preceding quotation is from a foreword prepared by John A. Brashear for the Autobiography of John Fritz.

It seems equally fitting, however, that it should be quoted again in announcing the forthcoming autobiography of Dr. Brashear. It is appropriate that there should be this bond between these two men, for the qualities that Brashear eulogized in Fritz are the qualities that made Brashear great and that endeared him to all who came within the sound of his voice.

The necessary space is not available in MECHANICAL ENGINEERING for more than a few excerpts from the autobiography which will be published during September by The American Society of Mechanical Engineers. But the selections printed here will be appetizers to those who desire to read of a great personality. The Foreword furnishes an estimate of his spirit in so far as it is possible for humans to measure the reasons why a great soul is great. In the Author's Preface "Uncle John" reveals the secret of his life happiness, and in the chapter on the Making of the Twelve-Inch Reflector we get glimpses of his great sacrifices and the strenuous efforts he exerted after the long day in the iron mill to make a telescope that would reveal the beauties of the heavens not only to him and his wife, but to all his neighbors and friends, for his great joy was in sharing with others. This chapter shows his painstaking care, his perseverence to success through great difficulties, and it reveals the devotion of his wife who was so much a partner in his life.

The story of a modest millwright who was led by his love of the stars to a career of great service for science and mankind will be a source of inspiration to the generations to come.

The autobiography was written at odd moments during the last eight years of Dr. Brashear's life. At the time of his death it was unfinished, but his great store of personal correspondence furnished ample material for the completion of his life story. William Lucien Scaife, a long-time Pittsburgh friend of Dr. Brashear's, supervised the editorial work on the book, which is published by the Society under the guidance of the following Committee: Joseph Buffington, George Ellery Hale, Charles M. Schwab, Ambrose Swasey, Benjamin Thaw, and William Lucien Scaife. A special subscription edition will be offered to members of The American Society of Mechanical Engineers, and a popular edition will be issued by the Houghton Mifflin Company.

Foreword

IT IS not fiction that thrills us most. The strangest thing in life is truth; the most romantic thing in life is man. So the nearer we approach the truth about a man, the closer we come to romance more strange and thrilling than fiction.

The story of "Uncle John" Brashear, as he was affectionately called by literally thousands, is above all a romance. So is the story of almost any successful man. America, the land where all men are presumably born free and equal, where the immigrant can attain to anything but the Presidency and the poorest native-born need stop not even at that, America is full of romances. But among them all stands a unique figure, the simple, kindly figure of John Alfred Brashear.

For here was a man who, in an age so commercial and materialistic that success is more often than not measured in dollars and cents, remained steadfastly true to an ideal of perfection with utter disregard of material gain or loss; a man who was blessed with a love of beauty which kept him continually striving the while it tempered him into a concrete expression of that love itself. His is a unique figure, not because he fought and won from life success in a chosen work, though he did that nobly, but because life gave her gifts to him so generously.

Talk with any one who knew him and you will hear, not what he did, but what he was. Remarkable, indeed, when you stop to consider that in the making of astronomical lenses and instruments of precision he was the peer of any man of his time, and this not in America alone, but in Europe as well. Crusty old scientists came to him first because his genius could aid them in their work; they returned because they loved him. The inexperienced amateur wrote to him hesitatingly for help, and a correspondence ripened into a deep friendship which produced important investigations and discoveries in the scientific world. He had the supreme gift of giving himself, and the world is immeasurably richer because he gave himself so generously. For great as was his genius, far greater was the man.

It is characteristic of Uncle John that in writing his autobiography he should minimize his own importance. This modesty was not assumed. It was a fundamental part of his character. As long as he lived he never felt that he deserved the honors life brought to him, nor could he understand why he was singled out to receive them. He accepted them with a childlike simplicity and, like a child, he was pleased. But he did not comprehend. So he wondered why for a little while, and kept on working.

It is indeed difficult to explain how this simple millwright of Pittsburgh became one of its most distinguished citizens and a figure of international importance. Granted that he was the foremost maker of astronomical lenses of his day; that he was a

master in the art of making plane surfaces; granted that early in his career nearly every observatory in America and Europe, as well as some in the Orient, was using apparatus which he had made and that the boundaries of science were being continually widened through the perfection of his work. Granted all this and more, yet it does not explain the unusual position which Dr. Brashear occupied the last quarter of a century of his life.

Mechanical genius he certainly had. His numerous technical papers undoubtedly contained valuable contributions to scientific knowledge. But genius of this kind cannot explain why a man without formal education should, in the twentieth century, be chosen acting chancellor of a large university, or why he should be selected by Andrew Carnegie to have such a large share in the work of making and executing the plans for the Carnegie Institute of Technology. Mechanical genius cannot explain why Henry C. Frick, when he wanted to give a half-million dollars for educational purposes in Pittsburgh, should have selected John Brashear to handle the fund, a man whose entire life had demonstrated his inability to grapple successfully with financial and business problems. There was a genius other than mechanical which made John Brashear Pennsylvania's "best-loved citizen," the intimate of millionaires and paupers, of scientists, educators, and untutored workmen, the friend of the newsboy, the natural, easy playmate of little blind children. It was the genius of a rare personality.

Who can describe the peculiar genius of personality? It is as mysterious and unfathomable as life itself—a deep well within us which reflects back to the world not only ourselves, but the imprint of every one whose life touches ours. Uncle John, with his gift of making friends almost instantaneously, naturally called forth the best in all he met, and his radiant personality reflected, above everything else, love. His chief charm lay not in the fact that he was different from his fellows, but in the fact that he was so very much like them. His sympathy and understanding were spontaneous expressions of his love for all humanity, his confidence that a wise Creator would not allow any of the creatures of His handiwork to be entirely unworthy.

That All the World Might See

Uncle John's career, in spite of limited schooling, is an inspiring example of the capacity of the human mind to gain knowledge from every available source, and of the human heart to radiate its light to every living creature within its range. He combined the ability to work consistently with a real love for the object of his labor, and an unquenchable desire to share it with every one who could be interested in it. His desire for a telescope was as much yearning to acquaint the whole world with the beauty of the heavens as it was to see it himself. Much as he loved and revered his science of astronomy—and surely no man has ever loved it more—he said and he believed that "the science most worth while in this world is that of extracting sunlight from behind the clouds and scattering it over the shadowed pathways of our fellow-travelers." He loved the stars; their beauty and sublimity fascinated him. But because he believed that "there is nothing that contributes more to the elevating and ennobling of the human and spiritual in man than the sight of some of God's beautiful work," he loved them infinitely better. When, late in life, he undertook to raise funds to build the new Allegheny Observatory, he did not rest content until it contained a room where any individual, regardless of race, creed, or color, should be permitted to learn of his beloved starry heavens.

In an age like the present, when clever publicity so often envelops the less great in a protective aura of unapproachableness, it is sometimes forgotten that the truly great are supremely simple, and that familiarity with them breeds not contempt, but increased respect. The man who is great to those who know him best is great indeed, and John Brashear was great indeed. It is said that at one time six thousand students in Pittsburgh knew him familiarly as "Uncle John," many of them well enough to call upon him for help and advice. He bore the test of intimacy and close association with old and young alike. Nothing about him was unreal or assumed. The sincerity which made him a great man made him an equally great friend.

It is to the eternal credit of America that, in the year 1920, at the very time when lecturers and writers (particularly those from England) were finding in American civilization a worship and respect for nothing except the commercial and material, a simple millwright in Pittsburgh should have been accorded such honors and homage as are bestowed on few; that a man whose ideals commercialism never lowered should have such public respect paid him as is seldom witnessed in any country. Virtue may be its own reward. After all, why not? Still it is good to see the last years of a worthy life crowned with the honors it so well deserves. It is well to feel that there remains everlastingly in the heart of a man a deep respect for the qualities that a rampant commercialism may attempt to deride.

If those who are interested in the education of American youth want to place before them the inspiration of a modern life of love, work, and service, they will do well to acquaint them with the story of John A. Brashear. For his life, as he has written it, is youth speaking to youth, and unless we who are older have hoarded the spark that keeps age forever young, we shall find ourselves outside the ranks of those who can best appreciate his delightful excursions into the past. Uncle John was all but eighty when they placed his ashes beside those of his wife in a crypt in the Allegheny Observatory, but the soul that passed on to take its place among the elect of the immortals was a youthful soul that maturity and accomplishment had failed to age.

Eternal Youth

For Uncle John spring never lost its thrill. The return of life to earth never lost its power to flood his being with new vigor and fill him with the exuberance of youth. In such moods he was compelled to find some form of self-expression outside of the ordinary. One of the last springs he spent on this "round old earth" he was seen emerging from his door with a bucket of aluminum paint in one hand and a good-sized brush in the other. The sunny morning was no brighter than the expectant smile on Uncle John's face. Out on the lawn were two urns which the Allegheny Park gardeners for years kept filled with plants and flowers for him. With a youthful step he crossed to the urns and soon they were resplendent with fresh paint. Uncle John returned to the house. Standing at the top of the front steps, his desire for self-expression still unsatisfied, his glance fell on an urn similar to his own on the lawn across the street. Without consulting the estimable but rather dignified ladies who lived there, he proceeded to decorate their urn as he had done his own. Recrossing the street he caught sight of the letter-box on the corner which Uncle Sam had decreed should be painted green, and in a few minutes it, too, was wearing a new spring dress of aluminum paint.

Then he turned toward home again with paint still in his can and enthusiasm still in his heart. He paused and looked around, open to suggestion as to further decoration. Now his eye rested on the police reporting box decreed by the city of Pittsburgh to wear a coat of red. The inspiration of spring and the availability of paint were too much for him, and the police reporting box, too, stood at last resplendent and glorified in the sunlight. Then, the paint and Uncle John both being exhausted, he returned to his home and his desk satisfied.

It is regrettable to have to report that the city did not take kindly to his innovation. In due time about three yards of printed rules, notices, and a questionnaire came from the Post Office Department, and two men, one with a bucket of green and the other with a bucket of red paint, restored the neighborhood to its accustomed appearance. But the rebuffs of an unromantic government, enmeshed in red tape and red paint, were not sufficient to kill the enthusiasm of this youth of all but eighty years. He smiled as he filed the unanswered questionnaire away, and retained to its fullest his inner urge to beautify the world about him.

The story of John Brashear is the story of a boy who loved the stars and who early determined that so far as he was able the whole world should have an opportunity to know the inspiring beauty of the heavens. In due time he fulfilled his early determination, and he did it so thoroughly that he never had time to grow old. One day the sun rose and ran its full course. As it set in undimmed splendor, its last rays crept gradually and silently up and over the figure of a man whose whole life had been a reflection of its power and beauty. Surrounded by his loved ones, Uncle John lay at peace, bathed in the rose light of the setting sun. Undimmed in splendor, he too passed beyond with the fading day.

Author's Preface

MANY dear friends have urged me during the past five years to put in printed form some reminiscences of my long life; and I romised one dear fellow, with uplifted hand, that I would do so. Now The American Society of Mechanical Engineers comes along and tells me I must do it. I see no way to refuse when this splendid body of men, who have made me one of their honorary members—placing me among a coterie of master-workers whose shoe-latchets I am unworthy to unloose—insist on my writing something of my life history.

Who will read my reminiscences if they are written? Perhaps a few who have known me for, say, half a lifetime; perhaps another few who are interested in my hobbies and who may get some word of encouragement, some helpful suggestion in the domain of the science I have loved so well; perhaps some fellow-workman from the old rolling mill, machine shop, or glass works, who knew me as a greasy millwright, or passable mechanic—some dear fellows still living, who, as younger men, used to go down with me at lunchtime on a cold winter day, in the ashpit of a rolling-mill furnace, to listen to my stories of the stars, as I pictured them on a piece of sheet iron with a lump of chalk; perhaps some few of the more than one hundred thousand who have listened to my lectures during the past forty years; or a few of my old Sunday-school scholars, still living, whom I used—wickedly—to take after Sunday school to the little cottage on the South Side hills to show them the beauties of the solar spectrum in my library, as the light from a slit in my window blind passed through that first bisulphide of carbon prism, made by my own hands. Or it may have been to show them a great sunspot, projected on the ceiling through my first telescope, made by "Ma" and me after three years of night labor; for at that period of my life, I had to gain a livelihood in the mill in the daytime.

Perhaps some of the good people will read these reminiscences who have been fellow-workers in the domain of our beautiful science of astronomy and astrophysics and who have helped me to "push forward the frontiers of human knowledge." I may possibly count, too, on those who have urged me to this difficult task. I know my dear friends and loved ones, who gave me kindly sympathy and helpfulness through many years of hard work, will read what they know comes from away down deep in my heart.

But, after all, my one big hope is that my humble effort in jotting down these items from life's memorandum book may help some struggling soul to master some of the problems of life, and of the beautiful in science, which will contribute new chapters of discovery to the now unknown and help to make this old oblate spheroid move smoother on its axis. For, aside from all knowledge, all science, I have long ago learned that "it is worth while to do even the smallest kindness, as we go along the way. Nothing is lost, no dewdrop perishes; but, sinking into the flower, makes it all the sweeter."

The happiest days of my life have been spent in endeavoring to lend a helping hand to the other fellow; whether he was a prince or a pauper, a savant or a poor chap seeking for some little knowledge of things good and beautiful, a teacher of men or a lover of kiddies; and while my love of the beauties of the skies has not abated one jot or tittle from the time I had my first view in my old home town to the day I write this paragraph, my chief joy has been to hand these beautiful things over to the other fellow, that he, too, might share in them.

John A. Brashear.

Pittsburgh, Pa., 1912.

Dr. Brashear's friendliness of soul is reflected so brightly and uniformly throughout the record of his life that the selection of any one chapter for reproduction here was not an easy task. His friends, and all who ever saw him took pride in being classed as friends, know of the romance of his career and will appreciate the riches in store for them in his autobiography. They will be sympathetic in this difficulty of selecting one phase for record here. However, the chapter which follows on making the Twelve-Inch Reflector was chosen because it reveals many of the qualities that made Brashear great and further because it could be taken easily from the context.

Chapter VI: Making the Twelve-Inch Reflector

DURING the winter of 1877 we procured, through Heroy & Marrenner, of New York, glass disks for the reflecting telescope which we had decided to make after my first talk with Professor Langley. We decided to make it of as large diameter as we could handle in the little shop; so we fixed upon twelve inches as the maximum diameter of the glass. It was not difficult to procure the disks, nor were they very costly; so, fearing a repetition of my unfortunate accident in breaking one of the object-glass lenses, we ordered and received two very excellent disks.

A focal length of ten feet was decided upon, and the grinding and fining tool readily prepared for commencing the work. The emery was washed for the different grades, and the disks were cut out of the square plates—just how I cannot remember at this writing. So Ma and I commenced the work that was to take we did not know how long. It all had to be done after my daily work at the mill, and it would not, it could not have been done without the deep and abiding interest of my wife.

Our evenings were frequently interrupted by visitors who wanted to see the heavens in the five-inch telescope which was mounted in what was then the garret of our home, but I do not and did not regret the delay, so great was the pleasure of our visitors at seeing the moon, planets, star clusters, nebulae, and occasionally a comet, in our telescope. But it required many months of labor before we had carried the work far enough along on the reflecting telescope mirror to do the polishing and testing.

Dr. Draper's splendid work, which had been loaned me by Professor Langley, gave full directors for testing the surface or curve of the mirror (Foucault method); and this was supplemented by letters from Dr. Draper himself with whom I had become acquainted by correspondence.

Unfortunately, I had no place where I could make these tests except the open space under the house, and this had to serve the purpose for the completion of the twelve-inch. After many nights of polishing, figuring, and testing, I concluded that the glass was as good as I could make it under the conditions of temperature changes that it had to undergo in working it in the little shop and testing it under the house. One of my greatest mistakes or blunders was that owing perhaps to the limited time at my command each evening, I did not wait long enough after polishing to see the effects when the increased temperature caused by the polishing had subsided or distributed equally in the mass of the disk. This can be explained to the reader, unacquainted with the delicate methods employed in testing an accurate surface, in this way: If the warm hand were pressed upon such a surface as I am describing for, say, ten seconds, and if the glass was a few degrees cooler than the hand, a cameo of the hand could be raised on the surface. If then the surface were polished before the raised impression of the hand had subsided, this raised figure would be polished off; and then, when the glass would come to a normal temperature, there would be an intaglio or depressed figure of the hand, instead of the raised or cameo figure we had before. This fact is well known to all opticians who have to deal with accurate optical instruments.

But at last our twelve-inch was ready to receive its coat of silver. A splendid tube had been made ready for me by my young friend Edward Klages, a carpenter by trade: and I had made a pattern and had a casting made, with a temporary though rather light equatorial mounting for it. This was set upon a brick foundation and a platform built around it so that observations could be made within our sky limits, which, unfortunately, were restricted in the south and southeast. But we had a fair portion of the sky at our command.

There were several known methods for silvering front surfaces, but at the time my own knowledge of chemistry was limited and I found that the chemist I consulted could give me but little information on silvering the front surfaces of glass, though quite a number of processes for silvering the inside of mirrors, like reflectors, looking-glasses, etc., were known. Dr. Draper's modification of the Cimeg Process was tried time and again; and as silver was a pretty costly affair for me, I was much discouraged, though at times I succeeded in getting a fair, but not satisfactory, surface of silver.

The mirror had already been tried on the moon with its unsilvered surface, and while its light value was only about one-eighth of what it should be, the defining powers were very promising.

My attention had been called by an English friend in the Adams mold shop to a journal printed in London called the *English Mechanic and World of Science;* I borrowed a few numbers and found there a method of silvering by a process requiring heat. So my wife and I prepared to make a trial of the new porcess. I found everything in readiness when I came home from the mill; and after supper we went to the little shop where the water was soon warmed in the containing vessel by steam heat from the boiler, as rigorous cleanliness in all the processes had to be observed. We had poured the silver solution with its reducer to change it to the metallic form; and you can imagine our delight and joy when we saw a beautiful deposit of silver covering the surface.

But, alas, alas, our joy was soon turned to sorrow, to grief, to keen disappointment that never could be described in words, when we saw and heard our disk crack from edge to center. Not to this day have I determined the real cause of the disaster, although two causes might explain it: unequal heating of the mass of the glass (but this was done so carefully that the second explanation may be more satisfactory) or the possibility that a jet of cold air, coming through a crack in the side of the workshop and impinging upon one side of the glass, cooled it at one point, and hence the rupture.

I do not like to write about this second disappointment in our optical work when we appeared to be just at the climax of success; for this last failure seemed to affect me more than the first one. Failure after all these months, and just when we had reached the goal. What visions I had destroyed in a moment. One of them was the wonderful view I should have of the planet Mars, then coming into the best position for observing that it had been or would be in for years. It was the year 1877, when Professor Asaph Hall discovered the two satellites of the planet.

If I remember correctly, I slept little or none that night, though my dear wife tried her best to cheer me by saying we could finish another glass, as we had both the disk and the experience. I went to the mill the following morning; I walked around like a crazy man; I could not collect my thoughts or concentrate them upon anything. In fact, I think it would have been a godsend if there had been a breakdown in the machinery that day to take my mind off that broken mirror.

About four o'clock in the afternoon I stopped and pondered for a moment, and this expression came from me, and could almost have been heard, I am sure, had there been any one near me: "What a fool you are, to worry this way; this worry will never mend that broken glass." I am not certain that I was a believer in telepathy then, or that I am now, but somehow I felt in my innermost soul that something was going on at home. I started home as early as possible that evening, and as I climbed the hill it was not with the same heavy heart that I had as I walked down it that morning. As I opened the door I was met with a smile and a kiss, and then dear Ma asked me to go out to the little shop before we sat down to supper. I thought possibly something unfortunate had happened out there. But instead, what did I see? The little shop in prime order, a fire burning under the boiler, engine oiled ready to start, and the extra disk in the lathe ready to have its edge turned with the diamond tool and its surface roughed out to the approximate curve. Could any one have done more? The memory of that moment, filled with the love and confidence of the one who was more than life to me, I can never forget. To make a long story short, in about two months from that evening, in the early spring of 1878, the new twelve-inch mirror was ready to be silvered.

I had made quite a number of experiments with various methods of silvering by this time, and at last I found a method, or rather a modification of a method, which I had seen in the *Scientific American*, called Burton's Method, by which I succeeded in obtaining most admirable results in silvering mirrors on the front surface, although it was originally intended for back surfaces, looking glasses, etc. So simple, so certain was this method, that I at once sent a communication to the *English Mechanic and World of Science*, describing it in full for the benefit of my amateur friends, of whom there were at that time, literally speaking, scores who were trying to make their own reflecting telescopes.

Little did I think at the time that this method would become *the* method, and be universally used for front-surface mirrors. The formula has been published in perhaps every chemical journal in the world; and although I am writing this note more than forty years after I had the pleasure of giving it to the world, without money and without price, I often have pleasant reminders of the value of my first humble contribution to the makers of reflecting telescopes.

Almost forty years later I stood in the laboratory of the Mount Wilson Observatory, admiring the beautiful silvered surface of the great one-hundred-inch reflecting telescope mirror, made by my old-time friend Professor Ritchey. Expressing my pleasure to him, he replied: "Well, it was silvered by Brashear's Process." Many other methods have since been devised; but I know of none more certain and more easily applied. I think we silvered the surface of the great seventy-two-inch mirror for the Dominion Observatory at Victoria, British Columbia—made by Mr. McDowell at our workshops and finished in April, 1918—in just about two hours and thirty minutes, including the operations of cleaning, mixing chemicals, and final polishing of the surface.

Phoebe S. Brashear, Who Played a Big Part in the Making of the 12-Inch Reflector

It can readily be seen from this description that there was no more experimenting on the new twelve-inch mirror; and, after a beautiful bright coat of silver was deposited upon its surface, and upon that of the small flat diagonal mirror for reflecting the beams from the central cone to the side of the tube, as in the Newtonian type of telescope, we were ready for the first clear night and our first look at the heavens.

I am sure that I did not audibly express a soliloquy at the sight that met my eyes as I placed the telescope on the Star Cluster in Perseus, the Nebula in Andromeda, the binary star Albireo in Cygni. Not even the views in the thirteen-inch refractor at Allegheny could, to my mind, exceed in beauty the glorious views in the twelve-inch reflector. There was a reason for it too. Not that the glass Ma and I had made was better intrinsically than the Allegheny Observatory telescope, but because rays of light from these heavenly objects did not suffer from what is called residual chromatic aberration; or, in other words, all bright objects seen in a refractor are more or less colored; and much light is absorbed in passing through the glass lenses. Some light is lost by reflection in a silvered-glass telescope, but since there is no separation of light rays in the reflector, all bright objects are seen in their normal tints. Take for instance the binary star Albireo (Beta Cygni). Where one star of the system is orange yellow, the companion is a cerulean blue. With the gathered light of as large a glass as the twelve-inch, these two stars are pictures of beauty one can never forget—two brilliant diamonds, orange and blue, shining with their transcendent luster in that far-off setting in yonder blue sky. I shall never forget that

first night with the twelve-inch which Ma and I enjoyed, not ourselves alone, but also our neighbors around us.

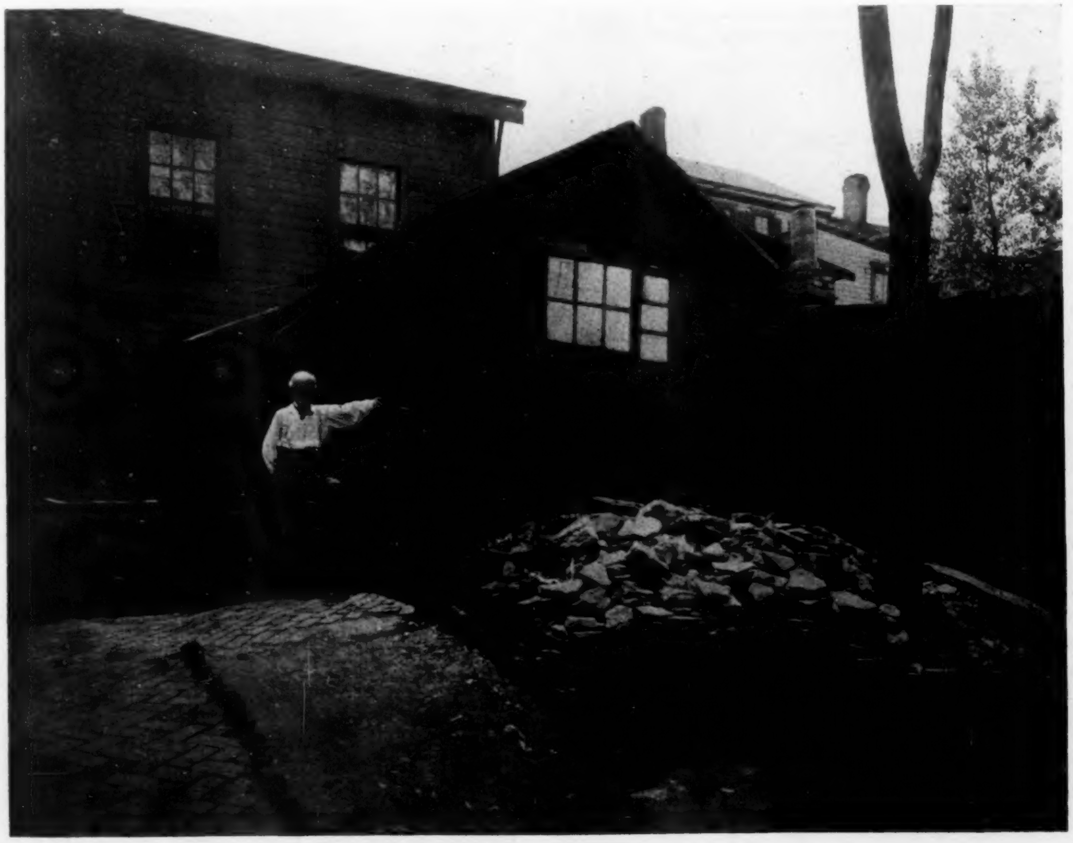
The twelve-inch reflector has had a useful life. For several years I used it for observation, making a study of many of the comets, the surface of Jupiter, and the floor of the crater Plato on the moon with it. I then loaned it to Professor Langley for a part of the apparatus with which he was making some important research at the Allegheny Observatory. Later on it was loaned to Professor Very, a former assistant of Professor Langley who had gone to the observatory of Salem, Massachusetts; then to Professor Hale, and lastly to Professor Very again, who had it in his posession for four or five years. After my old home and the workshop on the hill had been purchased by the good women of Pittsburgh for a social settlement, I had the good fortune to secure the mirror for the museum to be kept in the house, although Professor Very was quite loath to give it up, as it had aided him greatly in his astrophysical studies.

I cannot pass over this period of my struggles without stopping long enough to pay tribute to my good friend Dr. Henry Draper, who gave me some of my first words of encouragement. I had become acquainted with him through correspondence, as mentioned before, and he was never too busy to answer my letters in such a way as to help me solve the problems which were troubling me in the work I loved. His letters found me a toiler in the rolling mill, and together with his researches and his work on The Construction of a Silvered-Glass Telescope and Its Use in Celestial Photography, they opened a new world, a new heaven to me, and I know I was only one of the many earnest toilers of science befriended by his great heart. Indeed, his book was of almost inestimable value to hundreds who were enabled to make their own instruments through a knowledge gained by studying it.

I find among my possessions a letter he wrote me in early February, 1878, which may give some idea of his sympathetic understanding and desire to help in my problems:

> Your very interesting letter has come to hand and I am glad to hear from and learn that you have had such success. Your improvements on the various processes are very ingenious and important. I can sympathize with you about cracking your mirror for I lost one in almost exactly the same way.
>
> You will find, no doubt, a considerable improvement in the action of your telescope by grinding and polishing a flat mirror. Most of the plate glass one can buy is apt to be irregular locally and the image is much injured by it. By taking three disks of plate glass and grinding one side of each of them alternately on the other two, you can get a flat surface. In making your polisher, use as hard a pitch as you can and polish one glass completely before polishing at the others. But use the others occasionally on the pitch tool to keep it flat. It is a difficult job to make a perfectly flat surface, but you can test it by the Foucault Process by trying it in connection with your concave mirror; in other words, instead of putting the lamp and eyepiece in front of the mirror, put them at one side of the optical axis and direct the light by your flat mirror. You can then see what errors it gives to the beam of light from the concave mirror. On looking at a star with your telescope, if the flat mirror is slightly convex or concave the star will look like a small cross instead of a disk.
>
> As to eyepieces, it will probably be best for you to buy rather than make them. They are not expensive, but are troublesome to construct. You might use the eyepieces or lenses of a microscope if you can get one. Stackpole and Brother of 49 Fulton Street, New York, can inform you where you can purchase them.
>
> I have sent by this mail a pamphlet on my discovery of oxygen in the sun which I beg you to accept as a testimonial of esteem for your perseverance and well-directed labor. Please make my respects to your wife; such a partner is an invaluable assistant as I know from similar experience.
>
> Very truly,
>
> Henry Draper.

After my good friend had passed over to the Summer Land, I had the pleasure of continuing my friendship with members of his distinguished family. In after years I went out to his old observatory at Hastings-on-the-Hudson, where I spent two grand, aye, glorious, hours delving into the work of that famous workshop, two hours that will linger in my memory as long as life can last. No one outside the Draper family has ever visited that sacred spot that appreciated it, enjoyed it, drank in its reminiscences, its story of labor, toil, and anxious waiting for breaking clouds more than I did. As I stood by the noble sixteen-inch telescope and remembered the work it had done in the first lunar photograph; when I remembered that it was the pioneer or so many hundreds of telescopes of its kind that had gladdened the heart of the struggling amateur; when I stood by the grand twenty-eight-inch and thought of its maker and the blotting out of his noble life, I could not repress a tear of sorrow and I asked myself the question, "Does death end all?"



Brashear, in 1913, Standing in Front of His First Workshop

Lignite Distillate

Its Possibilities as an Internal-Combustion-Engine Fuel

By CHAS. E. KERCHNER,[1] GRAND FORKS, N. D.

This paper presents data on tests made with a small Hvid engine operating on lignite oil, as compared with gas oil and kerosene. Lignite oil, when suitably distilled, is shown to be an efficient and likely fuel for the internal-combustion engine. Since the by-products of lignite are valuable, its oil may become of commercial importance when scarcity of petroleum products is felt, and even sooner in those regions where vast deposits of this material are found, such as the Dakotas and Montana.

THE subject of low-temperature distillation of low-grade fuels has been given much thought and attention by engineers and chemists for some years, especially in European countries, notably in Germany. A considerable amount of research work has also been done in this country on the low-temperature distillation of bituminous and lignite coals and on the use of the carbonized residue and the resulting by-products. It has been found that certain of these by-products are suitable for commercial use. For example, the gases driven off can be used as a city gas, or the ammonia contained in the gas and gas water can be recovered as ammonium sulphate, a valuable fertilizer; or, as anhydrous ammonia, for refrigeration and other commercial purposes. The tars resulting from the carbonization of bituminous coal have been found to yield a variety of oils, such as creosoting oils for the preservation of timber, waterproofing and preserving oils for

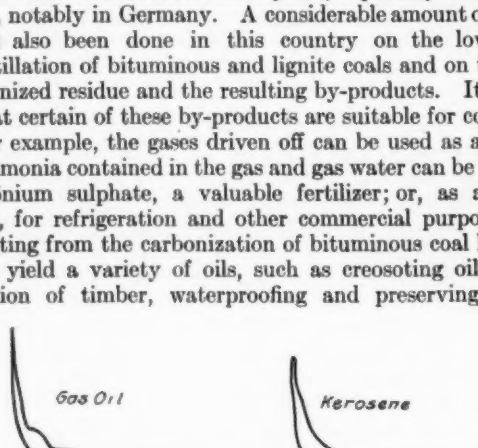


Fig. 1 Typical Pressure-Volume Cards with Different Oils

leather, cotton, and other fabrics; and from the lighter oils has come benzol which has been found to burn well in internal-combustion engines. The pitch residue has been found to make an excellent binder for use in the briquetting process.

While some research has demonstrated the suitability of the lighter oils derived from the carbonization of bituminous coal for internal-combustion-engine use, the author has found no data available concerning actual tests of lignite oils in internal-combustion engines. It was for the purpose of determining the suitability of lignite oils for internal-combustion-engine use that the tests described and discussed herein were originally undertaken. Later, when it had been determined that lignite oils could be successfully burned in an internal-combustion engine, comparative tests were made on lignite oil and on two commercial fuels, gas oil and kerosene. In each case physical characteristics, ignition, and combustion characteristics were studied in addition to the economy of the engine when operating on these fuels.

Source of Fuels Tested

The lignite oil used in these tests was distilled in one simple cut from a crude-tar mixture obtained from the distillation in closed retorts of North Dakota lignite coal and was not further refined. The distillation was carried on in the research laboratories of the School of Mines of the University of North Dakota under the direction of Dean E. J. Babcock. The gas oil used was a product of the Federal Oil Company and came from the Tulsa, Oklahoma, district. The kerosene used was a product of the Standard Oil Company of Indiana.

Type of Engine Used

The engine used in these tests was an 8-hp. Thermoil engine of the semi-Diesel type made by the Hvid Manufacturing Company, of Evansville, Indiana. The cylinder is $5^3/_4$ in. bore by 9 in. stroke. The engine is designed to run at 450 r.p.m. with a compression pressure of 400 to 500 lb. per sq. in. The engine has no auxiliary ignition apparatus, ignition being induced by the heat of compression alone.

Method of Conducting Tests

The economy runs were conducted according to the A.S.M.E. Code. Fuel weights as recorded by sensitive scales were checked

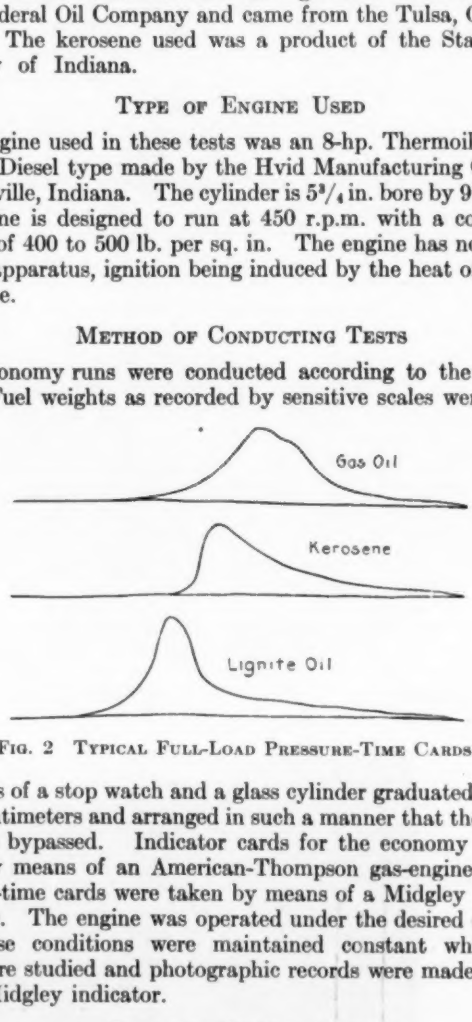


Fig. 2 Typical Full-Load Pressure-Time Cards

by means of a stop watch and a glass cylinder graduated to read in cubic centimeters and arranged in such a manner that the fuel tank could be bypassed. Indicator cards for the economy runs were taken by means of an American-Thompson gas-engine indicator. Pressure-time cards were taken by means of a Midgley gas-engine indicator. The engine was operated under the desired conditions, and these conditions were maintained constant while optical cards were studied and photographic records were made by means of the Midgley indicator.

Pressure-Volume Cards

Typical pressure-volume cards as taken with an American-Thompson gas-engine indicator are shown in Fig. 1. It is interesting to note that pressure-volume cards taken with the Midgley gas-engine indicator checked closely with those taken by means of the American-Thompson indicator. However, the wavy expansion line due to inertia effects in the pencil mechanism of the American-Thompson indicator were entirely absent in the cards taken with the Midgley indicator. This was to be expected since the latter indicator employs a beam of light to trace the diagram. On account of the close check between pressure-volume cards taken with the two indicators and on account of the greater ease in handling the American-Thompson indicator, the latter was used throughout the economy runs.

Pressure-Time Cards

Pressure-time cards for the engines operating on lignite oil, gas oil, and kerosene are shown in Fig. 2. On these cards a $^3/_4$-in. image represents 400 lb. per sq. in. pressure. A study of the pressure-time cards for kerosene shows the absence of fuel knock. The combustion and expansion lines indicate the smooth-burning characteristics of this fuel when burned in the Hvid engine. Gas oil, like kerosene, burns in the Hvid engine with freedom from fuel

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knock. The combustion and expansion lines on this card indicate smooth burning. The extremely long period of fuel admission necessary for the engine to carry full load on gas oil is vividly shown on the full-load card. The engine was running below speed on full load and the large amount of work done during each power stroke is seen by an inspection of the expansion curve of the full-load card.

A reference to the pressure-time card for lignite oil indicates that the ignition and combustion characteristics of this fuel, when burned in the Hvid engine, are quite similar to those of kerosene and gas oil. The lack of fuel knock and the lack of after-burning are indicated by the smooth expansion line. The full-load card indicates the high pressure of compression and ignition due to the heavy charge of fuel. The engine was unable to carry full load at rated speed when burning this fuel, and the full-load card plainly shows the labor of the engine under these conditions. Since the lignite oil is a heavier fuel and since the distillation range was rather wide, the oil undoubtedly contains too high a percentage of heavy hydrocarbon compounds to be burned in this engine with facility.

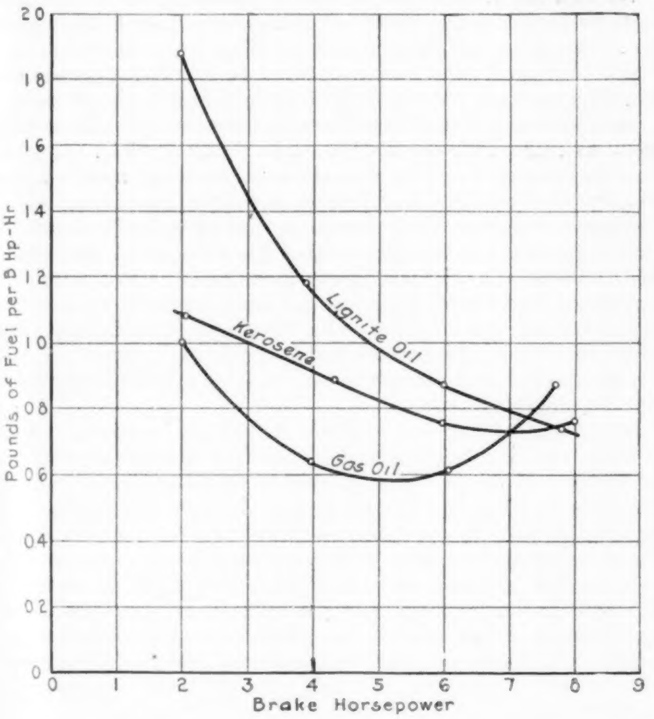

Fig. 3 Fuel-Consumption Curves, $5^3/_4 \times 9$-in. 8-hp. Hvid Engine Operating with Gas Oil, Kerosene, and Lignite Oil

Discussion of Curves

Fuel-consumption curves for the engine are shown in Fig. 3 and efficiency curves in Fig. 4. A comparison of the curves in Fig. 4 shows gas oil to be the most economical at light loads and lignite oil to be the most economical at full load. Kerosene, the fuel for which the engine was designed, is shown to be the most economical when the entire range in power is considered. Kerosene is also seen to be the most suitable fuel for the engine when considering thermal efficiencies, while at the same time this fuel shows the lowest mechanical efficiencies. Mechanical efficiencies, however, are not considered a reliable source of information in high-speed internal-combustion-engine work, because of the great opportunity for errors in the calculated efficiencies due to the high speeds and high pressures involved. The Internal-Combustion Engine Code recently revised by The American Society of Mechanical Engineers advises against the use of the indicator card for determinations of efficiency where engine speeds of 400 r.p.m. or more obtain. Therefore it is evident that thermal efficiencies referred to indicated horsepower are likewise unreliable as an accurate means of comparison. It is considered in this case, however, that thermal efficiencies based on brake horsepower are entirely in keeping with the character of the fuels and the conditions under which these fuels were used, since the Hvid engine was equipped with an oversize pulley, 24 in. in diameter, to stabilize conditions on the brake and to insure reliable data in regard to brake horsepower developed.

It is seen that kerosene shows the best consistent efficiency referred to brake horsepower at all loads, and that this efficiency is fairly constant under all loads. This is as might be expected, since kerosene is the fuel for which the engine is designed and therefore the fuel for which the best thermal efficiency should be expected. Lignite oil shows a somewhat better thermal efficiency referred to brake horsepower at full load, but this increase in efficiency over kerosene is more than offset by the difference in the behavior of the former as compared with the latter. When operating at full load, the amount of lignite oil required was necessarily large and admitted over a long period of time, resulting in a longer and later period of burning. The engine was observed to labor at full load, and some difficulty was experienced in maintaining the rated speed.

In comparing the three fuels used, both in regard to thermal efficiencies and with respect to operating conditions, kerosene was found to be the fuel best adapted to that engine. The engine was observed to operate more smoothly and to respond better to load changes when burning kerosene than with either gas oil or lignite oil.

While the engine operated smoothly on gas oil and showed high thermal efficiencies on part loads, much the same difficulty was experienced at full load as with lignite oil, that is, the engine ran less smoothly, was observed to labor, and the speed fell below rating. The engine could be started on gas oil as well as on kerosene, but it was found impossible to start on lignite oil. In making the tests on lignite oil the engine was first started and warmed up on kerosene before lignite oil was admitted to the combustion chamber.

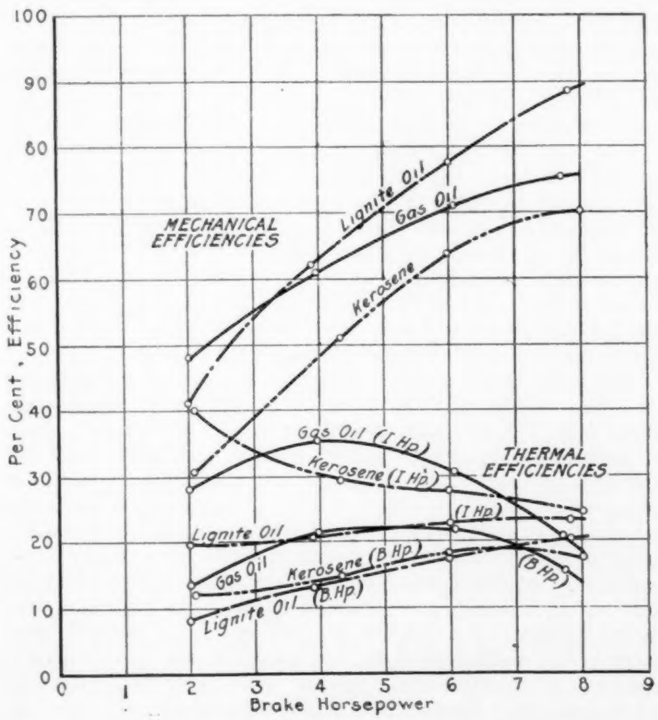

Fig. 4 Efficiency Curves, $5^3/_4 \times 9$-in. 8-hp. Hvid Engine Operating with Gas Oil, Kerosene, and Lignite Oil

Physical Characteristics of Oils Tested

The accompanying table affords a comparison of the physical characteristics of the fuels tested. It is interesting to note that while the lignite oil has a much higher specific gravity and a higher viscosity, both the flash and burning points and the calorific value are below the corresponding characteristics of either the gas oil or kerosene. This is due to the fact that the distillation range of lignite oil was wide enough to include certain of the light and volatile fractions of the crude lignite-tar mixture, and due to the presence

of a small quantity of these fractions, the oil exhibited a low flash and burning point. The quantity of the heavier fractions present is apparently quite large in comparison with the lighter portions since the calorific value is rather low.

It must be remembered when comparing properties of the lignite oil used in these tests with the properties of kerosene and gas oil, that this oil had not been refined to a degree comparable to either of the other oils. Only one simple cut or distillation was made to obtain the oil since it was desired to determine whether this fuel could be successfully burned in an internal-combustion engine without the necessity for further expense or refinement. Obviously, all undesirable features in an oil can not be eliminated in one process of distillation. The water content in the lignite oil was due entirely to the lack of mechanical separation, which could easily have been almost entirely eliminated without additional expense in a commercial plant.

TABLE 1 PHYSICAL CHARACTERISTICS OF OILS TESTED

Physical Characteristics	Lignite Oil	Gas Oil	Kerosene
Viscosity, 60 deg. fahr.	1.040	1.030	0.964
Viscosity, 100 deg. fahr.	0.974	0.958	0.930
Specific gravity, 32 deg. fahr.	0.992	0.833	0.827
Specific gravity, 70 deg. fahr.	0.953	0.825	0.812
Gravity, deg. B., 70 deg. fahr.	16.9	39.7	42.4
Flash point, deg. fahr.	145	185	158
Fire point, deg. fahr.	160	195	165
Calorific value, B.t.u. per lb.	16,554	18,740	19,164
Water and bottom sediment, per cent	2.00	0.1	None
Cold point, deg. fahr.	Unobtainable	Unobtainable	Unobtainable

The Necessary Distillation of Crude Lignite Oil

At the very beginning of the investigations concerning this oil and prior to the tests discussed above, it was desired to determine whether the crude lignite oil and tar as obtained from the vats in the carbonizing process could be burned in an oil engine. Accordingly, an attempt was made to burn the crude oil and tar mixture without any further refinement. The engine was thoroughly warmed up to insure the best of conditions for vaporizing and igniting the crude mixture. Then, by means of a bypass arrangement the supply of fuel on which the engine was being operated was shut off and the crude mixture was admitted. Numerous trials were made, each of which resulted in failure to burn the oil. This was not unexpected since the specific gravity of the mixture was 1.05 and the mixture showed a tendency to separate into heavier and lighter portions and appeared "stringy" when handled.

Subsequent to the above experiments a distillate was prepared from the crude-tar mixture in which the distillation temperature ranged from 212 deg. fahr. to 500 deg. fahr. This range in temperature resulted in an oil which was thought to compare favorably as regards gravity with the oils with which the lignite distillate was to be compared. When tried in the Hvid engine this oil was found to burn rather successfully. Hence, it was decided to make the actual comparative tests on a lignite distillate of this gravity despite the fact that it was somewhat heavier than the commercial fuels tested, namely, gas oil and kerosene. This decision was reached in view of the fact that the still used in the research laboratory in the distillation of the crude mixture was of very limited capacity and the distillation process was necessarily a laborious and tedious one. Furthermore, it was deemed advisable from an economic viewpoint, if this fuel should be commercialized, to limit the distillation to as few simple cuts as possible in order to procure a desirable fuel from the by-products of lignite carbonization at the lowest possible cost.

Lignite Statistics and Possibilities

The United States Bureau of Mines has estimated that lignite comprises 1,051,290,000,000 minable tons of 2000 lb. each. Of this amount 964,424,000,000 tons are in beds underlying the western half of North Dakota and extending into South Dakota and northeastern Montana. It has also been estimated that approximately 40 lb. of tar per ton of air-dried lignite might be recovered if carbonization were carried on in tight retorts with a moderately low carbonization temperature of 1000 deg. fahr. to 1200 deg. fahr., and that of this amount from 25 to 50 per cent of the type of lignite oil used in these experiments might be obtained. Then, if all of the lignite in North Dakota, South Dakota and Montana were carbonized, there would be given off in the form of tar about 40,000,000,000,000 lb. which would yield from 10,000,000,000,000 to 20,000,000,000,000 lb., or about 1,250,000,000,000 to 2,500,000,000,000 gal. of lignite oil of the type used in these tests. Obviously this amount could not be produced in a single year, nor likely in a decade. Thus, it is seen that lignite oil can never be expected to replace petroleum and its products to a very large extent. However, if the carbonizing process were carried on in closed retorts in sufficient volume to supply the demand for medium- and high-grade coals in the territories in which low-grade fuels are found, the resultant tars recovered should provide liquid fuel in a quantity which would go far toward supplying the local demand for that type of fuel.

No data are available on the cost of production of the oils used in these tests and any statement in this respect would necessarily be in the nature of an assumption. However, if (as mentioned above) enough lignite were carbonized to supply the present demand for medium- and high-grade fuels in the territories where low-grade fuels are found, the resultant tars recovered should be sufficient to make their distillation economically feasible. It must be remembered, however, that since lignite oil is merely a by-product of the carbonizing process and since the amount of oil recovered is rather small in comparison with the bulk of coal carbonized, it can scarcely be expected that these oils could be distilled and marketed at a price much lower than that of present petroleum products. The value of lignite oil as a fuel for internal-combustion-engine use will probably not be fully appreciated until the present abundant supply of petroleum and its products becomes seriously depleted and a substitute for this fuel is needed to assist in supplying the increasing demand.

Since lignite oil was found to burn successfully in the engine used in these tests, it is felt that lignite oil of similar or lighter grade can be successfully burned in a number of semi-Diesel type engines with little or no change in their design. Probably the only change required in some cases would be a change in the design of the fuel-injection apparatus. This should necessitate but slight cost in order to adapt these engines to a fuel of this type. It would be desirable, however, to decrease the range in the temperature of distillation of lignite oil and thus obtain an oil of more uniform grade. This should decrease or eliminate entirely the slight amount of tarry residue noted in these tests when the engine was operated on lignite oil.

Conclusions

The results of these investigations might be summarized as follows:

1 The crude-tar mixture as taken from the tanks in the low-temperature distillation process can *not* be burned in an internal-combustion engine without refinement.

2 Lignite oil (distillate) *can* be successfully burned in an internal-combustion engine.

3 The behavior of lignite oil in an internal-combustion engine compares very favorably with commercial oils of similar grade.

4 The physical characteristics of lignite oil indicate that it can be refined for use as an acceptable substitute for various grades of commercial liquid fuels.

5 The ignition and combustion characteristics of a fuel are dependent upon the chemical structure of the fuel and upon the type of engine in which the fuel is burned.

Wood-Preservation Research

Director E. R. Weidlein of Mellon Institute of Industrial Research of the University of Pittsburgh has announced the founding of an Industrial Fellowship on the treatment of timber. This research, which is being sustained by the Grasselli Chemical Company, of Cleveland, Ohio, and is being conducted by Dr. A. M. Howald, has for its purpose a study toward improvement of the methods of applying zinc chloride in the wood-preservation industry.

Investigational work which was begun during 1923 will be continued throughout the present year. An experimental wood-impregnating plant is maintained for practical tests of processes. Research is at present being done under the supervision of Dr. Howald on the development of a method of increasing the permanence of zinc-chloride treatments of timber by the addition of petroleum oils.

Pulverized Fuel at the Cleveland Electric Illuminating Company's Lake Shore Plant

By W. H. Aldrich,[1] Cleveland, Ohio

The author of this paper does not consider himself an authority on pulverized fuel, and therefore intends to confine himself chiefly to the experience of the Cleveland Electric Illuminating Company in their recent installation of pulverized-fuel-burning equipment. The art is so comparatively new in central stations that there has, perhaps, been more written on its theory than on concrete practice.

The Illuminating Company, with a total installed kilowatt capacity of 258,000, has 12,240 hp. of rated boiler capacity equipped to burn pulverized coal. There are four 3060-hp. Stirling boilers, each provided with B. & W. superheaters and Power Specialty Company's steel economizers. Each boiler is really two Class P boilers, fifty-five tubes wide, set up side by side in one boiler setting.

The fuel-preparation and -burning equipments were supplied by the Combustion Engineering Company.

The coal it is proposed to burn comes largely from the Pittsburgh No. 8 district and analyzes about as follows:

Moisture, per cent	5
Volatile, dry, per cent	32
Fixed carbon, per cent	54
Ash, per cent	15
Sulphur, per cent	3
Heating value, dry, B.t.u.	12,500

Owing to the comparatively low moisture it was decided not to install driers, though provision was made so that they could be installed later, if necessary. Tests made by the Milwaukee Railway and Light Company, who were the first to use pulverized coal on a large scale in central-station practice, showed that coal with less than 7 per cent moisture could be handled without difficulty and that the degree of moisture had no appreciable effect on efficiency.

Description of the Coal-Handling and Burning Apparatus

Coal in the form of slack is brought into the boiler house by the regular conveyor belt and is distributed into bunkers at the top of the building. From these it flows by gravity through 12-in. iron pipes to the pulverizing mills in the basement. These mills are made by Raymond Bros., and there are twelve of them, or three to a boiler. Each is of six-tons-per-hour capacity, and is driven by a direct-connected 100-hp. 2200-volt motor. In this make of mill the coal is pulverized by six rollers suspended and pivoted from a revolving spider. The centrifugal force throws these rollers out against a bull ring where the pulverization takes place. A revolving paddle-like feeder, automatically controlled by air pressure, keeps a proper supply of coal fed to the mill. The coal is ground to such a fineness that 70 per cent will pass through a 200-mesh sieve and 90 per cent through a 100-mesh sieve. The pulverized coal is taken from the mill and conveyed to the pulverized-coal bunker through large galvanized-iron pipes by the air blast from an exhauster fan working under about 10 in. air pressure. The exhauster fans were built by the B. F. Sturtevant Co., and are driven by 50-hp. 2200-volt direct-connected motors. The exhauster pipes carry the pulverized coal to the top of the boiler-room building where it passes through a cyclone separator, from which the coal can be fed by gravity directly to the pulverized bunkers on one side of the boilers, or to a screw-conveyor system which supplies the pulverized-coal bunkers on the other side of the boilers. The cyclone separator is vented to the roof through a smaller auxiliary separator also discharging into either bunker or conveyor. The supply of air returns to the mills on the suction side after depositing the coal in the separator. It is, in fact, a closed system except for the vent through the separator.

The bunkers are of large capacity and are built of concrete. It has been found that concrete bunkers are preferable to steel-plate bunkers because, due to the high conductivity of steel and the thinner walls, the coal will cool more rapidly. Rapid cooling of warm, moist coal forms condensation, and this moisture forms a paste with the pulverized coal which impedes its flow and distribution.

The conveyors for carrying the pulverized fuel to the bunkers on the opposite side of the boilers from the separators, are of the regular screw-conveyor type closed in on top and driven by 15-hp. motors.

The pulverized fuel is fed from the bunkers to the burners by Lopulco feeders. The feeders are bolted to the bottom of the bunkers and consist of a revolving screw with a paddle wheel on the end of the shaft. A current of air under from 6 to 10 in. of water pressure is admitted at a point where the paddle wheel helps to mix the coal and air, and carries the coal thence downward through a 4-in. pipe to the burner. The feeder is driven by a $1^1/_2$ hp. d.c. motor with a speed control from a central switchboard. Each feeder is built to deliver from 615 to 2400 lb. of coal per hour from 100 to 300 per cent rating. There is a separate feeder for each burner.

There are sixteen burners, eight on a side, for each boiler setting. The burners are pointed downward, and at the discharge end are flat in shape with an opening about 14 in. long by $^7/_{16}$ in. wide. It has been found that this form of nozzle exposes a much larger surface for mixing with additional air and for absorbing radiation from the flame than does a solid stream from a round burner. The air supplied to the feeders is preheated by being drawn through the bottom of the boiler setting before passing through the fan. The temperature of this air is about 100 deg. fahr. at the feeders.

The furnace averages about 25 ft. wide by 32 ft. across the combustion chamber and is about 52 ft. high from ash doors to peak, having a total volume of about 29,000 cu. ft.

The boiler settings are built with hollow walls up to the arches, or about half-way up the settings. Most of the air for combustion is admitted through finely balanced, spring-controlled doors on the sides of the boiler, and passes through the hollow wall to the front of the wall where it enters the furnace through numerous 9-in. square openings in the wall under the arch. The hollow wall serves the double purpose of supplying preheated air to the furnace and helping to cool the walls of the combustion chamber. At present there are no means of telling accurately what the temperature of this air is, but from a recording thermometer inserted in middle of the air passage near its outlet it has been found to be about 165 deg. at 175 per cent rating.

The boilers are equipped with water screens at the bottom of the furnace to keep down the furnace temperatures at this point and prevent fusing of the ash. The water screen, being a part of the circulating system of the boiler, adds to the heating surface of the boiler and is not a source of loss. It consists of forty-two 4-in. boiler tubes spaced 12 in. apart and inclined downward toward the center of the furnace at an angle of 8 deg. from the horizontal.

Induced draft is supplied by two Sturtevant cinder-vane fans to each boiler. These fans have 10-ft.-diameter wheels and are direct-driven by 150-hp. 2200-volt BTS-type motors. These motors have a variable speed of from 126 to 360 r.p.m., provided for by the shifting of the brushes.

All the apparatus involved in the combustion of the fuel is controlled from a central switchboard and may be operated manually or automatically by the steam pressure. This control system was installed by the Bailey Meter Company. The feeder motors are started and stopped and their speed is regulated, either individually or in groups of eight, from this board. The induced-draft fans are started and stopped and their speed is also regulated from this board. The damper mechanism is interlocked with the fan mechanism so that it may be worked automatically in connection with the fan speed.

[1] Cleveland Electric Illuminating Co.

Contributed by the Power Division and Cleveland Committee and presented at the Spring Meeting, Cleveland, Ohio, May 26 to 29, 1924, of The American Society of Mechanical Engineers.

The company's pulverized-fuel boilers have so recently been started up that little can be given in the way of costs of operation and test results. It can be said, however, that all apparatus is functioning properly, and that there has been no serious trouble of any kind in starting up and in training employees to handle equipment entirely new to them. No trouble has been experienced in handling the fuel without drying except at the time of first starting up in midwinter, when the building was not closed in. Then, due to leakage from the roof and excessive cold in contact with the conveying and handling apparatus causing condensation, the moisture in the screw conveyor necessitated frequent shutdowns of this piece of apparatus for cleaning out. This, however, was but a minor incident, and the trouble was eliminated when the building was closed in. It only goes to show that there is a limit to the moisture in the coal if it is to be successfully handled. As a precaution against spontaneous combustion the bunkers are periodically cleaned out, and the coal is run out of them whenever possible before a boiler is shut down for a long period of time.

It may be well to mention here that the superheat exceeded the guarantee to such an extent as to prevent the operation of the boilers at high ratings. Work is now being done to correct this by removing some of the superheater tubes.

Up to the present time there has been no serious trouble with slagging or erosion of the furnace walls, the arches and walls above the air-cooled walls showing no signs of burning or spalling.

There has been no trouble from slagging of ash in the bottom of the furnace. A steam-jet conveyor is now being installed to carry the ash to a tower over the railroad tracks where it can be run into railroad cars.

The boilers are equipped with Vulcan, and the economizers with Diamond, soot blowers. The boilers are blown once in 24 hours, and the economizers less often. At present the fouling of the boiler is due more to fine ash lodging in pockets than to adhesion of slag and ash to the tubes.

Owing to the fact that work is still being done on the induced-draft fans and control apparatus, and that there is at present no means of accurately weighing the fuel to each boiler, no absolutely accurate tests have been made on these boilers. One $19\frac{1}{2}$-hr. check test on one of the boilers at 150 per cent rating, using track weights and bunker inventory, showed 0.91 per cent unaccounted-for losses and may therefore be considered fairly accurate. This test showed 83.71 per cent efficiency for the boiler and 90.71 per cent combined efficiency on boiler and economizers. Under normal operation the combustible in the ash runs about 0.2 per cent.

Preparations are now being made to start acceptance tests on these boilers in the near future.

To summarize, the experience gained from a few months' use of pulverized fuel at Lake Shore Station is such as to lead the operating man to feel that it is clean, safe, easy to prepare and fire, and is productive of high efficiency in the boilers.

Data on the Pulverized-Fuel Equipment

The following data relative to the pulverized-fuel equipment at the Cleveland Electric Illuminating Company's Lake Shore Station, may prove of interest:

Heating surface in superheater per boiler, sq. ft.	6,550
Heating surface in economizer per boiler, sq. ft.	22,080
Heating surface in water screen (= 246 sq. ft. projected), sq. ft.	835
Furnace volume, total, cu. ft.	29,150
Furnace volume to water screen, cu. ft.	26,000
Cu. ft. of furnace volume per sq. ft. of heating surface	0.95
B.t.u. per cu. ft. at rating	4,110
B.t.u. per cu. ft. at 350 per cent rating	16,733

The following miscellaneous data are taken from the specifications:

Pulverized-Coal Equipment

12 pulverizers, each of 6 tons per hr. capacity on Pittsburgh No. 8 coal
2 closed pulverized-coal bins (110 tons each) for each boiler
12 Lopulco waste-heat driers (if driers are used)
(Coal feed determined by screen revolution. Preparatory to pulverizing, coal to be crushed to a size that will pass through a $1\frac{1}{4}$-in. ring.)

Heating surface of water screens per unit, sq. ft.	835
Combustion air for four boilers at 300 per cent rating, cu. ft. per min.	35,000
Maximum air pressure at fan outlet, inches of water	15
Draft required at each level in furnace at 300 per cent rating, inches of water	0.4–0.5
Pulverization required: 65 per cent through 200 mesh; 85 per cent through 100 mesh; 98 per cent through 50 mesh	
Men required for normal operation up to 225 per cent rating, not more than	8

Auxiliary Air Inlets

288 9-in. by $10\frac{1}{4}$-in. observation type
96 air registers to control air entering hollow walls
24 furnace doors $16\frac{1}{4}$ in. by $20\frac{1}{4}$ in

Flue Gas, etc.

Rating Per cent	CO_2 per cent	Lb. coal per burner per hr.	Combustible ash in furnace bottom, per cent	Combustible in flue dust, per cent
100	16	615	0.2	0.6
150	16	930	0.2	0.6
225	15	1560	0.2	1.0
300	14	2420	0.2	1.5

Preparation of Coal

Kw-hr. per ton: Mills, 14.5; screen conveyors, 1.0; feeders and blowers, 4.0
Feeders: 64 5-in. type, single individual d.c. motor drive
Burners: 64 4-in. diam. nozzles, right-angle fantail type
Water screens: 42 4-in. tubes per boiler, 24 ft. 6 in. long
Water-screen leaders: 2 per boiler $7\frac{1}{4}$ in. continuous and 2 per boiler $11\frac{3}{4}$ in. continuous.

Blowers

4 single No. $4\frac{1}{2}$ steel pressure Sturtevant, 20,000 cu. ft. per min., 15 in. static head.

Feeder Piping (4-in. wrought-iron black pipe)

32 65 ft. long and 32 30 ft. long.

Conveyors

2 screw-type, 14 in. diam. by 75 ft. long, 36 tons per hour
4 screw-type, 14 in. diam. by 85 ft. long, 36 tons per hour.

Mills

Raymond 6-roll, 6 tons per hr., moisture 4 to 5 per cent.

Motors (G. E. Co.)

Number	Voltage	Current	Hp.	R.p.m.	To drive
64	220	d. c.	1.5	500–1500	feeders
4	2200	a. c.	100	1200	feeder blowers
6	440	a. c.	15	900	converters
2	2200	a. c.	150	350	exhauster-drier
12	2200	a. c.	100	450	mills
12	2200	a. c.	50	1200	mill exhausters

Valves, Etc.

B. & W. tri cocks operated from firing floor
4 Edward cast-steel combination drumhead stop and check valves for 4-in. diam. feed
4 Yarway seatless blow-off valves set in tandem with Yarway double-tightening valves.

Fans

8 No. 10 Sturtevant Cinder-vane fans, 95,000 cu. ft. per min., 360 r.p.m. net static head, 4.7 in. of water; temperature of inlet gas, 360 deg. fahr.; hp. required, 150; size of fan, 10 ft.; fans with two hubs with 10 arms; size of arms, 3 x 3 x $\frac{3}{8}$ in.; total net resistance in fan, 4.7 in. of water; static efficiency, 51 per cent; ash elimination, 50 per cent at 300 per cent rating.

Boilers

Stirling type, class 13 Twin, No. 55, 275 lb. pressure. Blue gas, 15 per cent CO_2.

Superheaters

Capacity, per cent	175	200	250	275	300
Superheat, deg. fahr	221	236	263	273	279

Operation

Maximum drop in CO_2 from furnace to outlet (entering economizer), 1 per cent

Rating, per cent	100	150	225	300
Temp. of gases leaving boiler, deg. fahr	455	490	555	620

Tests

All tests shall be made in 30 days after erection. Economizer test to be of 24 hr. duration. Pittsburgh No. 8 coal, 12,870 B.t.u. dry, 4 to 5 per cent moisture. Guarantee of coal is as specified.

Rating, per cent	Efficiency, boiler only, per cent
100	85.4
150	84.5
225	82.3
300	77.0

Guarantee: 225 per cent constant rating with no fusing of ash sufficient to interrupt operation.

Discussion

C. G. Spencer.[1] Papers on pulverized fuel in central stations have been for the most part on expected performances and projected designs. Mr. Aldrich's paper is one of the first on the experience gained in operation. For this reason it is of special interest and value.

Even though the use of pulverized fuel in central stations is an innovation, there are tendencies which indicate that the conclusions of even a few months ago, based on experience at that time, may well be reconsidered. Engineers with experience under different conditions are coming to believe that, with most coals, driers are desirable as insuring high efficiency and continuity of service.

The advantages to be gained by a low moisture content and a uniform moisture content in the coal entering the mills may be summarized as:

An Increased Boiler Efficiency. The moisture entering the furnace with the coal is evaporated into steam, superheated to the temperature of the exit gases and lost up the stack. For ordinary conditions, the energy thus lost is equivalent to 0.1 per cent in boiler efficiency for each per cent of moisture in the coal, or 0.5 per cent in boiler efficiency for a 5 per cent moisture content. This is not

[1] Engineer, McClellan and Junkersfeld, New York. Mem. A.S.M.E.

an important item in the summer when the surface moisture is low, but it does become of importance and represents a dollar loss during the winter months when the coal contains snow or ice and the demands on the plant are at a maximum.

Mill Capacity. The capacity of a mill is, to a marked degree, a factor in the moisture in the coal. It is not unusual in a plant where provision is made to weigh the coal from the mills as at Cahokia to observe a 25 per cent reduction in mill capacity, due to an increase of 2 to 4 per cent in moisture.

Power for Grinding. The reduction in mill capacity due to moisture is accompanied by an increase in the kilowatt-hours per ton for milling.

Uniformity of Feeding. Stratification with a variation in the rate of feeding results from the milling and delivering to pulverized coal bins of coal of different moisture contents. With layers of coal of different moisture content in the bins, the feeders, operating at constant speed, increase or decrease the coal entering the furnace, depending on whether they are supplied by coal of lower or higher moisture. This variation in coal feed disturbs the furnace condition, resulting either in excess air or excess temperature with slag. This lack of uniformity in dryness has been observed to require a 30 per cent change in feeder speed to maintain a constant evaporation from a boiler, with all other conditions remaining the same.

Absence of Arching in Bins. Probably one of the most annoying experiences in the operation of pulverized-fuel furnaces is the arching of the fuel over the feeder screws. This tendency to arch is reduced as the moisture content in the coal is reduced.

Freedom from Condensation. Low-moisture coal reduces the tendency in cold weather for condensation to collect and form a paste throughout the milling, conveying, and storage systems.

Improved Furnace Conditions. Probably the greatest gain from a low and uniform moisture content is in the improved furnace condition, reflected by an absence of variation in rate of coal feed and improved combustion, since less heat is absorbed at the point where it is most needed by the evaporation of excess moisture.

An interesting development in the past month is the putting in service at Cahokia of a Raymond mill of 15 tons per hour capacity. With boilers and prime movers of large capacity there has been a need for pulverizing mills of greater capacity than those available to date. This particular mill is now in regular operation. Two additional Raymond mills of the same capacity will be installed this summer. Of equal interest in the development of larger units is the 20-ton Fuller mill, which will also be installed at Cahokia this summer. This mill will operate on the air-separation principle, and, while it embodies the Fuller ball-mill principle, the design has been worked out to bring the center of gravity low and to insure strength and rigidity. The total weight of this unit is 60,000 lb. It will be direct-connected to a 200-hp. motor. Two feeders individually motor-driven supply the raw coal to the mill. The kilowatt-hour input, including air-separation and feeder motors, is 13.5 kw-hr. per ton.

Valuable data are to be expected from the Lake Shore installation on the ash recovered from the stack gases by the cinder-vane fans. The problem of removing ash from the waste gases because of possible undesirable effect of the ash settling is probably the most discussed point in connection with pulverized fuel in central stations located in thickly settled communities. The Lake Shore installation is the first to go in service in central-station practice where provision has been made to recover the ash.

It is gratifying to learn that the superheater performance at Lake Shore is exceeding the guarantees, since it is relatively easy to reduce excess superheat and difficult to increase it.

The results given by Mr. Aldrich of a check test at 150 per cent rating are excellent both for combustible in the ash and efficiency, and would indicate that guaranteed performances will be equaled.

H. G. Barnhurst.[1] This paper is of particular interest to any one studying the new development, and is additional evidence that pulverized coal has established itself and is affording means of obtaining the highest efficiency in the burning of coal.

There are, of course, more ways than one of handling problems of this nature, and although new plants are now being constructed, embodying other means of preparing and burning pulverized coal, nevertheless, the plant in question is undoubtedly arranged to give high efficiency and quite satisfactory operating conditions.

[1] Advisory Engineer, Fuller-Lehigh Company, Fullerton, Pa. Mem. A.S.M.E.

Among the items mentioned is that of moisture in the coal. A limit of 7 per cent moisture as handled satisfactorily at Milwaukee was due to a considerable percentage of inherent moisture in the coal. Drying is essential to obtain the most satisfactory operating conditions all the year around, and means should be at hand to dry the coal in some manner.

The best results can only be obtained when the surface or free moisture content is below 2 per cent, and it is my opinion that better efficiencies can be obtained by drying the coal before it reaches the finished state. It is well to note that provision has been made in the plant referred to so that driers can be installed later if found desirable.

It is also interesting to note that flat or fantail burners are used. Burners of this type permit rapid heat penetration and prompt ignition.

The vertical method of firing used is satisfactory, and permits burning of a wide range of coals of varying analyses. The horizontal method, although limited to the burning of coal containing a fairly high volatile content, nevertheless permits a higher combustion rate per cubic foot of furnace volume, and where plants are so situated that a supply of high-volatile coal containing approximately 25 per cent and upward can be obtained, the horizontal method of burning has a number of advantages.

Slag has not proved to be the source of trouble anticipated and prophesied by the manufacturers of stoker equipment. When the furnace and the points of supply for combustion air are properly designed, the so-called water screens are not necessary for the prevention of slag, and involve complications.

Additional heating surface of various types is useful, however, in many instances for the recovery of heat otherwise lost in ash and radiation.

The writer is strongly in favor of handling pulverized coal in pipes permitting dustless transportation. Screw conveyors have been used for many years, however, and although harder to keep clean are quite dependable.

One item of particular interest is the statement regarding the percentage of ash recovered. Fifty per cent recovery certainly places pulverized coal burning on an equal basis with stokers. In most cases, furthermore, there is practically no smoke nor unconsumed carbon in the ash. The ash is so fine it will be distributed to such an extent that serious objections cannot develop.

The discharge of ash is practically the only serious objection that can today be brought against the use of pulverized coal in urban districts, and more familiarity on the part of the public with the great area over which the very fine ash is imperceptibly spread will doubtless reduce this objection to its proper insignificance.

The earlier objections to the use of pulverized coal for fuel for boilers was mainly due to wrong impressions as to the cost of preparation, danger, and the development of slag. These have all been successfully brought under control so that with the final overcoming of the ash difficulty, all doubts as to the general applicability of pulverized coal will be dispelled.

Summing up, Mr. Aldrich's paper describing the installation and operation in question is very informative and gives valuable corrobative data concerning the efficiencies and convenience obtained through the use of pulverized coal.

Oral Discussion

R. D. DeWolf.[1] As a result of experience with burning pulverized coal under two Bigelow-Hornsby boilers since last August, we have come to the conclusion that there is no necessity for driers where the moisture in coal is under 4 to 5 per cent. The installation is quite similar to that at Cleveland, with the same kind of mill, but at Rochester one 125-hp. motor is used to drive both the mill and the fan.

Most of the coal contains 4 to 5 per cent moisture as it comes to the bunker, and loses about 1 per cent going through the mill. The mill capacity under those conditions has been between six and seven tons. With very moist coal running 8 to 10 per cent, the mill capacity drops off.

[1] Ch. Operating Engr., Rochester Gas and Electric Corp., Rochester, N. Y. Mem. A.S.M.E.

With separately fired driers, I believe that the amount of heat consumed by the drier is greater than that thrown away in the stack gases where the boiler has an economizer; i.e., the temperature of the stack gases leaving the economizer will be lower than the temperature of the gas leaving the drier, and consequently the heat loss is less.

An analysis of accidents in cement mills during a period of five or ten years with 50 or 60 fatalities, shows that 75 per cent of the serious accidents were due either to the separately fired drier or to the pulverized-coal conveying equipment. Most of the accidents occurred at the same time: when the plant was shut down for repairs. In Rochester the conveying of the pulverized coal has been eliminated as the coal goes direct from the cyclone separator to the bunker above the boiler.

The use of driers has come from the development of powdered coal in cement plants, but conditions of operation in boiler plants are enough different from those in cement plants so that some of the features recognized as being necessary in cement mills are unnecessary in the boiler plant. At Rochester there is sufficient space so that if necessary, vertical driers using the waste gases from the boilers to effect the drying can be installed. Up to 5 per cent moisture, however, the mill does not lose very much in capacity, nor is there much trouble with combustion conditions in the boiler.

C. D. Zimmerman.[1] Without any difficulties whatsoever, we have been able to get test efficiencies in actual operation at the Lake Shore plant.

If a scientific investigation were made of the matter of ash, and a comparison made between stoker-fired boilers and powdered coal, I think that there would be more objectionable ash from stoker-fired boilers than from those using pulverized coal—in fact, we see no trace of the powdered-coal ash around the plant.

G. Keith[2] said that those who talked about moisture not making much difference were operating plants in which stoker-fired boilers could be relied on in case of trouble with the pulverized-coal equipment.

He said that with the 6-ton Raymond mills at Cahokia, mentioned by Mr. Spencer, running at an average capacity of about 5.7 to 6 tons per hr. with the moisture as high as 6 and 7 per cent, 19 kw-hr. per ton of coal ground was the input to the mills. With moisture as low as 3 per cent, the power input to the mill, including the fan and mill, was 11.8 kw-hr. per ton, and the capacity for a period of six hours was 6.5 tons per hr.

With regard to the boilers at the St. Louis plant, he said, although tests were not complete, they had run 8 days 24 hours a day at no time less than 140 per cent rating. The last 24 hours of the run was at 250 per cent rating, and the boiler was in condition so the operators could keep on running it. Very little slag was formed, he said, and he did not think he had ever seen a stoker-fired boiler that could be operated for a period of 200 hr. and be in as good condition to continue as that boiler was.

J. B. Johnson[3] said that his experience with powdered coal dated back eight or nine years. It had been said repeatedly that moisture must be kept down below various percentages ranging from five to six per cent, and he wished to call attention to his experience with too little moisture. The feed screws would allow the coal to flood through unless the moisture was maintained between 4 and 5 per cent, he said. He had found that below 2 per cent, pulverized coal would flow almost like water, and that the feed screws would not hold it back. The situation had been remedied by keeping the bunkers about three-quarters full.

G. E. Hines[4] asked if pulverized-coal-fired boilers would be advocated in an industrial plant where the steam demand varied from 50 to 225 and 250 per cent rating in three or four minutes.

The author answered that pulverized-fuel plants were most adapted for taking sudden fluctuations in steam pressure.

Theo. Maynz[5] said that he did not believe there was a stoker made that could compare in flexibility with the pulverized-fuel furnaces at the Lake Shore plant. At one time, he said, steam was badly needed due to a complete shutdown, and although the installation was far from completed, the boiler rating was raised from almost a complete shutdown to 250 per cent on one fan in less time than he could recall.

G. Keith added an experience of his, saying that when the power supply on feeders and blowers had been lost and the steam pressure had dropped 75 lb., it had been brought back in ten minutes with powdered coal.

H. G. Barnhurst told of a steel plant in Warren, Ohio, with pulverized-coal-burning equipment and supplied with current from the Ohio Public Service Company. One day in February when operating the boilers around 350 per cent rating, the current failed and the boilers were shut down. It was about two hours and a half before the repairs in the line were made, he said, and the pulverized coal was immediately turned on. The settings were fairly cold, but in three minutes and a half from the time the current was turned on the boiler was operating again at 300 per cent rating. Since then generators have been installed, which makes it impossible for this condition to occur again.

With reference to the recommendation of Mr. Johnson to maintain a moisture of 4 to 5 per cent to prevent flooding, it was evident that his feeders were not of the type known as non-flooding. Reducing the moisture, he said, certainly improved the handling, transportation, and burning of the coal, in that it was better mixed with air when blown into the furnace in a dry state, and more uniform furnace conditions obtained.

A. G. Christie.[1] This is an extremely interesting paper, and some of the discussion that has been offered has been very illuminating. Considerable discussion has been devoted to the question of drying. There have been some stories going around the country about the difficulties of using waste-heat drying, and as we have been discussing it, a few comments may be of interest.

I think the difficulties are largely due to lack of appreciation of the problems involved in using flue gases. If the flue gases get too cold leaving the drier, the dew-point of the gases is reached, and they are actually adding moisture to the coal rather than removing it.

Another difficulty is in fires, and that, I think, has been successfully overcome. If flue gases are used which have a rather high percentage of oxygen, these, passing through coal and heating it, particularly a high-sulphur coal, are trying to persuade the coal to catch fire, and are not trying to prevent it. However, with 15 or 16 per cent CO_2 there is such a lean oxygen mixture that it is almost impossible for it to support combustion, and if a fire should start, the drier can be shut off and the fire will smother itself, because CO_2 is one of the best smothering elements.

This leads to the consideration of the conditions that should exist in the drier, and I am very strongly of the opinion that quite hot gases rather than cool gases can be used for that purpose so as to keep well above the dew point in the exit temperature of gases from the drier.

H. F. Cover.[2] Nothing has been said about the unit system of pulverization. The Upson plant of the Bourne-Fuller Company has pulverizers installed with 500-hp. Stirling boilers. With coal at 10 per cent moisture and less, quite satisfactory service is obtained. There is no drier on the boiler, and no economizer. That we are not able to get higher efficiency is no doubt due to the fact that the boiler is subject to steel-mill practice; it is up and down all the time.

John VanBrunt.[3] The statement has been made that slagging trouble was not noticed, and no slagging trouble need be expected. Obviously, if a pulverized-coal furnace is operated with a high percentage of CO_2, temperatures will be reached which will be in excess of the fusion temperature of the ash, and if the ash strikes the wall at that temperature there will be rapid erosion of the brick and slagging of the ash. The purpose of the water screen which was

(*Continued on page 545*)

[1] Prod. Engr., Steam Dept., Cleveland Elec. Illuminating Co., Cleveland, Ohio. Jun. A.S.M.E.

[2] McClellan and Junkersfeld, New York, N. Y.

[3] Ch. M. E., United Verde Copper Co., Clarkdale, Arizona. Mem. A.S.M.E.

[4] V. P. and Ch. Engr., Ulen & Co., 129 Broadway, New York. Mem. A.S.M.E.

[5] Cons. Engr., 3326 Kenmore Road, Shaker Heights, Cleveland, Ohio. Jun. A.S.M.E.

[1] Prof. M. E., Johns Hopkins University, Baltimore, Md. Mem. A.S.M.E.

[2] Bourne-Fuller Co., Cleveland, Ohio.

[3] Ch. Engr., Combustion Engineering Corp., 43 Broad St., New York. Mem. A.S.M.E.

Recent Developments in Electric Locomotives

BY N. W. STORER,[1] EAST PITTSBURGH, PA.

The paper gives tabulated data of types, dimensions, weights, capacities etc., for a number of recent designs of locomotives. The reasons for the several types shown are given, and the designs are discussed. The conclusion drawn is that there is a tendency at this time toward the maximum axle loading with gear and side-rod drive for heavy freight service, and toward the individual drive with spring-supported motors for high-speed passenger locomotives. For direct-current locomotives with lighter axle loading, the axle-hung direct-geared motor has the field.

IT IS the purpose of this paper to describe some of the recent designs of electric locomotives and to discuss some of the tendencies in design, especially of mechanical parts.

While there have been comparatively few instances of steam railroad electrification since the close of the World War, there have, nevertheless, been several very important and significant electrifications that have stimulated the development of the electric locomotive and indicated world-wide interest in electrification. In spite of the poverty of the war-stricken countries in Europe, railway electrification is progressing or under active discussion in nearly all of them, stimulated in most places by the high cost of coal and the possibility of using water power. Two large installations are being made in South Africa; two or more in South America; Australia is in the market for additional electric-railway equipment; and others are progressing in the East Indies and Japan.

The principal new locomotives in which the company the author represents has had a part are listed, with their principal dimensions, weights, type, etc., in Table 1.

Paulista Railway Locomotives

Two types of Baldwin-Westinghouse locomotives were built for the Paulista Railway of Brazil, as shown in Table 1. The freight locomotive has six driving axles contained in two articulated trucks.

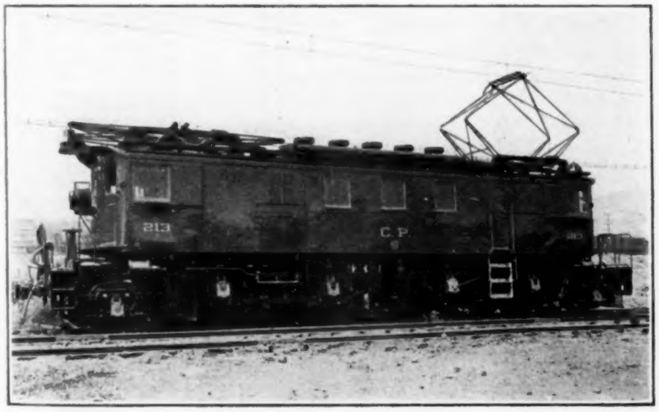

Fig. 1 Central of Paulista Passenger Locomotive

Each axle has a motor geared directly to it. The motors are wound for 1500 volts each and are operated with two or more in series at all times. There are three combinations of motors: first, six in series, giving one-third speed; second, three in series, two in parallel, for two-thirds speed; third, two in series, three in parallel for full speed. There is in addition a higher speed in each combination, obtained by tapping the fields of the motors. Regenerative braking is obtained at all speeds with full power.

In speed combinations the control system follows the precedent of the Baldwin-Westinghouse locomotives which have operated so successfully on the Chicago, Milwaukee & St. Paul Railway, but the control in general is simpler than that of the Milwaukee locomotives because there is neither train lighting nor heating to be supplied from the locomotive. The power for exciting the main motors during regeneration for auxiliary motors and for the locomotive lighting and control circuits is all furnished at a low voltage from a small motor-generator set, so that there is no high voltage on anything outside of the main motors and control apparatus except the motor of this motor-generator set. This makes a relatively simple as well as rugged and reliable equipment.

The cabs of these locomotives rest on spring-supported H-frames, which form a flexible link between the cab and truck frames. The H-frame carries the center pin. This construction gives a very easy riding cab.

The passenger locomotives, as in Fig. 1, are of the 2-4 + 4-2 type, each driving axle having a twin motor geared to a quill surrounding the axle, which is connected to the wheels by the well-known long helical spring in use on the New York, New Haven and Hartford Railway. The armatures and other electrical features of these twin motors are interchangeable with the motors of the freight locomotive so that this locomotive has one-third more

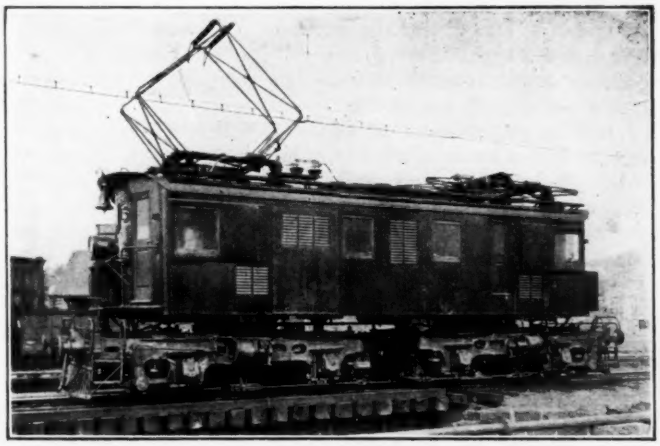

Fig. 2 Chilean State Local Passenger Locomotive

power than the freight locomotive with only four driving axles instead of six. This gives a much better utilization of the weight than would be possible with eight driving axles. The cab of this locomotive rests on spring supports but the center pin is carried directly in the cross-tie of the truck.

These locomotives are also designed for regenerative braking with full power on the motors.

Both of these locomotives have been remarkably successful in operation.

Chilean State Railways

The Chilean State Railways are equipped with overhead trolley with 3000 volts direct current. The four types of locomotive built for this railway all have motors geared directly to the driving axles. Like practically all foreign locomotives, these are designed for light axle loading, the rules of the railway placing the maximum weight per axle at approximately 40,000 lb. The switcher is of the usual standard, light, double-truck type, with four driving axles. The local passenger locomotive of Fig. 2 is similar to this but has articulated trucks. One notable feature of this locomotive is that the truck frames are cast in one piece, as shown in the photograph.

The freight locomotive of Fig. 3 is very similar to the freight locomotive for the Paulista Railway which has just been described, the chief difference being that the weight has been reduced somewhat, due to changes in the mechanical parts.

The passenger engine of Figs. 4 and 5 has a similar equipment, but has a pony truck at each end of the locomotive, which was deemed desirable on account of the higher speeds of operation.

The control equipments for these two locomotives are practically identical, each locomotive being arranged for three speeds with

[1] Genl. Engr., Westinghouse Elec. & Mfg. Co. Mem. A.S.M.E.

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corresponding motor combinations and three additional speeds from tapped fields. Full power regeneration at all speeds is also provided for.

New York, New Haven and Hartford Locomotives

The locomotives for the New Haven road listed in the table belong to what is known as the 0300 class and are duplicates of those built in 1919 for the same railway. They are built for heavy, high-speed, passenger service. While these locomotives are not of a new type, they are listed here because they are the standard of the New York, New Haven and Hartford and an order for twelve has just been completed. Another reason is to call attention to the different type. These locomotives, as shown in the photograph of Fig. 6, are of the 2–6–2 + 2–6–2 type. Each driving axle is driven by a twin motor through gears, quill, and springs. Each axle is independent, just as if it were driven by an axle-hung motor. The control equipment is complicated by the fact that the locomotive must run either from the 11,000-volt, single-phase, overhead trolley or from the 600-volt d.c. third rail in the terminal district of the New York Central Railway. However, the control is thoroughly reliable and the satisfactory performance of the locomotives is attested by the fact that after several years' operation with five of these locomotives, twelve more were purchased.

An interesting feature of this locomotive is the one-piece casting which constitutes the entire frame of the truck. This can be seen in the photograph. It is strong and relatively light.

Like the locomotives of the Chilean State Railways, these had to be designed for a light axle loading on account of the bridges over which they had to pass, and the one-piece truck frame assisted very materially in keeping the weight down to the desired limit.

TABLE 1 DATA FOR NEW ELECTRIC LOCOMOTIVES

Railroad		Number in service	Class of service	Contact voltage	Conductor type	Type of loco.	Class. by wheels	Driving wheels No.	Driving wheels diam.	Truck wheels No.	Truck wheels diam.
Paulista Railway	1	2	Pass.	3,000	Catenary	d.c.	2–4 + 4–2	8	63"	4	36"
	2	2	Frt.	3,000	Catenary	d.c.	0–6 + 6–0	12	40"	.	...
Chilean State Railway	1	6	Ex. Pass.	3,000	Catenary	d.c.	2–6 + 6–2	12	42"	4	30"
	2	11	Local Pass.	3,000	Catenary	d.c.	0–4 + 4–0	8	42"	0	...
	3	15	Frt.	3,000	Catenary	d.c.	0–6 + 6–0	12	42"	0	...
	4	7	Switcher	3,000	Catenary	d.c.	0–4 + 4–0	8	42"	0	
N. Y. N. H. & H. R. R.		12	Pass.	600 11,000	d.c. 3rd rail a.c. Catenary	d.c. & 1ϕ a.c.	2–6–2 + 2–6–2	12	63"	8	36"
Norfolk & Western		8 M.P.U.	Frt.	11,000	Catenary	a.c.	2–8–2	8	62"	4	33"
The Virginian		36 M.P.U.	Frt.	22,000 11,000	Catenary	a.c.	2–8–2	8	62"	4	33"
Pennsylvania	1	2	Pass.	650	3rd rail	d.c.	2–8–2	8	80"	4	33"
	2	1	Frt.	11,000	Catenary	a.c.	2–8–2	8	80"	4	33"

Railroad		Articulated trucks	Wheelbase Rigid	Wheelbase Total	Weight in Pounds: Total road wt.	On drivers	Per driving axle	Mech. parts	Equipment[1]
Paulista Railway	1	Yes	8' 4"	41' 2"	283,800	205,800	51,450	165,400	118,400
	2	Yes	14' 0"	37' 0"	234,300	234,300	39,050	144,050	90,250
Chilean State Railways	1	Yes	14' 5"	48' 4"	259,800	210,000	35,000	153,966	105,834
	2	Yes	8' 4"	26' 0"	160,000	160,000	40,000	93,000	67,000
	3	Yes	13' 9"	37' 0"	230,000	230,000	38,333	138,400	91,600
	4	No	8' 6"	27' 4"	137,000	137,000	34,250	80,900	56,100
N. Y. N. H. & H. R. R.		Yes	14' 3"	59' 6"	358,000	240,000	40,000	175,200	182,800
Norfolk & Western		No	16' 6"	37' 6"	414,000	300,000	75,000	251,500	162,500
The Virginian		No	16' 6"	37' 6"	414,000	300,000	75,000	.....	.....
Pennsylvania	1	No	22' 3"	54'11"	approx. 400,000	300,000	75,000	225,100	174,900
	2	No	22' 3"	54'11"	408,000	300,000	75,000	225,100	182,900

[1] Includes sand, air brakes, etc.

Railroad		Dimensions: Length overall	Width overall	Height trolley down	Regen. control	Motors: No.	Method of drive	Gear ratio
Paulista Railway	1	52' 11"	10' 7"	14' 10"	Yes	4 Twin	Geared quill	28 : 86
	2	50' 2"	10' 6.5"	14' 10"	Yes	6	Geared	16 : 63
Chilean State Railways	1	58' 5"	10' 6.75"	14' 4 7/16"	Yes	6	Flex. gear	21 : 56
	2	38' 9.5"	10' 7"	14' 2 3/16"	No	4	Flex. gear	21 : 56
	3	49' 9.5"	10' 6.75"	14' 4 7/16"	Yes	6	Flex. gear	15 : 63
	4	40' 0"	10' 6.75"	14' 2 3/16"	No	4	Gear	16 : 63
N. Y. N. H. & H. R. R.		68' 6"	10' 2.5"	Over d.c. trolley down 14' 9 1/2"	No	6 Twin	Geared quill	25 : 89
Norfolk & Western		48' 7"	10' 5"	16' 0"	Yes	2	Flex. geared jack shaft and side rod	21 : 100
The Virginian		.....	10' 5"	16' 0"	Yes	2	Flex. geared jack shaft and side rods	....
Pennsylvania	1	68' 2.5"	10' 3"	15' 6"	No	4	Flex. gear and side rod	50 : 98
	2	68' 2.5"	10' 3"	15' 6"	No	4	Flex. gear and side rod	30 : 118

Railroad		Tractive Effort in Pounds: One-hour rating F. V.	Per cent coeff. of adhesion	Continuous rating F. V.	Per cent coeff. of adhesion	Starting
Paulista Railway	1	20,960	10.0	14,240	6.9	54,400 maximum
	2	32,400	13.8	21,600	9.2	77,310 33% adh.
Chilean State Railway	1	25,800	12.3	19,800	9.4	70,800 maximum
	2	17,200	10.8	13,200	8.3	47,200 maximum
	3	31,200	13.6	24,360	10.6	75,900 33% adh.
	4[2]	23,000	16.8	11,000	8.0	45,210 33% adh.
N. Y. N. H. & H. R. R.		23,160	9.66	16,200	6.66	52,500 maximum
Norfolk & Western (2 M.P.U.)	8 P	108,000	18.0	90,000	15.0	185,000 maximum
	4 P	63,000	10.5	52,500	8.75	110,000 maximum
The Virginian		.....	.....	.....	.....	....
Pennsylvania	1	44,000	15.47	36,000	12.64	86,000 maximum
	2	59,000	19.72	50,000	16.66	100,000 33% adh.

[2] Self-ventilated. F. V. = force ventilated.

Railroad		Speed, Miles per Hour: One-hour rating	Continuous rating	Maximum safe	Horsepower of Locomotive: One-hour rating F. V.[3]	Continuous rating F. V.[3]	Builder of mechanical parts
Paulista Railway	1	42.8	47.2	65	2400	1800	Baldwin
	2	20.8	23.4	42	1800	1350	
Chilean State Railway	1	36.0	39.75	63	2460	2040	Baldwin
	2	36.0	39.75	56	1640	1360	
	3	21.5	23.0	44	1800	1500	
	4	10.5	12.75	35	640	384	
N. Y. N. H. & H. R. R.		32.6	38.4	77	2016	1656	Baldwin
Norfolk & Western (2 M.P.U.)	8 P	14.10	14.20	38	4060	3400	American
	4 P	28.30	28.40	..	4750	4000	
The Virginian		...	...	..	4060	3400	American
		...	...	..	4750	4000	
Pennsylvania	1	35.9	37.8	70	4100	3630	Penna. R. R.
	2	21.00	23.0	35	3300	3070	

[3] F. V. = force ventilated.

Norfolk and Western Locomotives

These locomotives, shown in Fig. 7, are designed for operation from an overhead trolley with 11,000-volt, single-phase, alternating current of 25 cycles. They are of the split-phase type, i.e., the single-phase current taken from the trolley passes through a transformer and phase converter on the locomotive and is transformed into three-phase current, which is used by the three-phase induction driving motors. These locomotives will be operated at 14 and 28 m.p.h., like the locomotives which are now in service. While following the same general system of control, they have, however, many improvements over the old ones, some of which are noted hereafter.

The most prominent difference lies in the mechanical design. These locomotives have a 2–8–2 wheel arrangement, with rigid frames, while the original locomotives were 2–4 + 4–2, with the cab resting on the trucks. A second important difference lies in the fact that only two motors are used on each cab instead of four, as in the original locomotive, although the capacity of the locomotive is approximately 30 per cent greater.

The main motors are mounted directly above the jackshaft and are arranged so as to be overhauled by lifting them out through a hatchway in the roof. The motors are arranged with collector rings on both ends of the rotor, located outside of the pinions and readily accessible. The pole-changing switches, reversers, and blowers are mounted on the motor frame, which gives an extremely compact job of wiring.

The liquid rheostats which are used for accelerating and for varying the speed of the locomotive are of an improved type, so designed that the engineer has individual control of all the rheo-

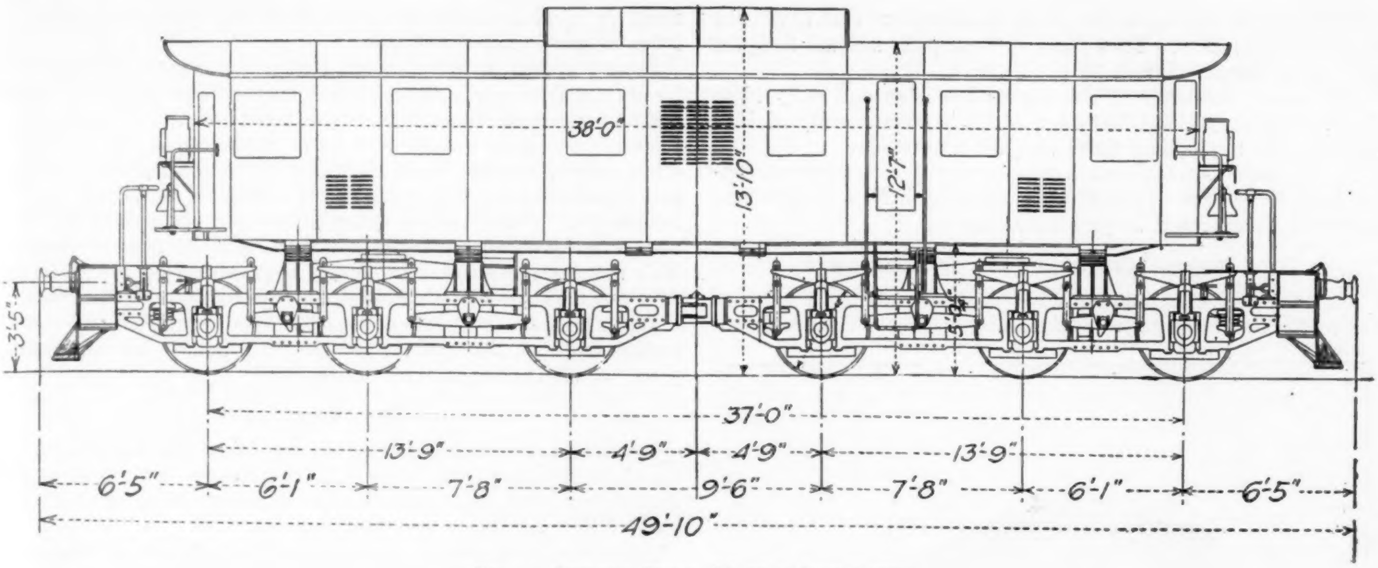

Fig. 3 Chilean State Freight Locomotive

stats. The electrolyte is in constant circulation and is kept cool by a current of air passing through it as it falls over shelves in the rheostat.

Oil-insulated transformers are used which are cooled by circulating oil through a radiator which is provided with a forced draft.

Each motor is connected to two pairs of drivers by means of gears, jackshaft, and side rods. These are of an extremely massive design suited for the heavy service for which they are intended. The gears are flexible, with a leaf type of spring.

The cabs are built for single-end operation since they are always operated in pairs.

The Virginian Railway Locomotives

The locomotives that are listed for the Virginian Railway are now under construction. They are designed, like the Norfolk and Western, for an overhead trolley with 11,000-volt single-phase current. The locomotives themselves are of the split-phase type with equipments duplicate of those on the Norfolk and Western locomotives, which have just been described. The mechanical parts have been modified somewhat, chiefly in order to fit them for operating with three or four cabs or motive-power units, coupled together, since it is desired to handle very heavy trains on the grades, which will require a locomotive with three motive-power units at the head of the train and three at the rear.

The Pennsylvania Locomotives

This locomotive, shown in Figs. 8 and 9, is one of three that are under construction by the Pennsylvania Railroad. They are designed for operation from an overhead trolley, with 11,000-volt, 25-cycle alternating current.

Like the Norfolk and Western locomotive, these are of the 2-8-2 design, with gear and side rod drive. However, they are variable-speed locomotives, designed primarily for heavy- and preference-freight service on the main line of the Pennsylvania, but are to be tried out in passenger service as well. Each jackshaft is driven by two single-phase commutator-type motors, each with a continuous rating of 760 hp., which are geared so as to develop the full rating of the locomotive of 50,000 lb. tractive effort at 23 m.p.h. These motors are furnished by the Westinghouse Company and consist simply of the armatures and the stator rings with the field laminations built into light castings which carry the windings and the rocker rings in which the brush holders are mounted. The bearings and the cradle which carry the stator are designed as a part of the mechanical part of the locomotive.

The gears are flexible, similar to those of the Norfolk and Western. The pinions of the motor next to the drive wheels are solid while those on the outside motors are flexible.

The cab is of the steeple type, arranged so the hoods can be removed to give access to the motor or for its removal. The cab itself is small and requires space simply for the motorman's compartments and transformer, air compressor, and a small amount of control apparatus. The reversers and blowers for the main driving motors are carried under the hood. Contrary to the usual custom, the air is exhausted from the rear end of the motor rather than being blown through it. This has the advantage of removing the hot air from the cab as well as making the commutator more accessible.

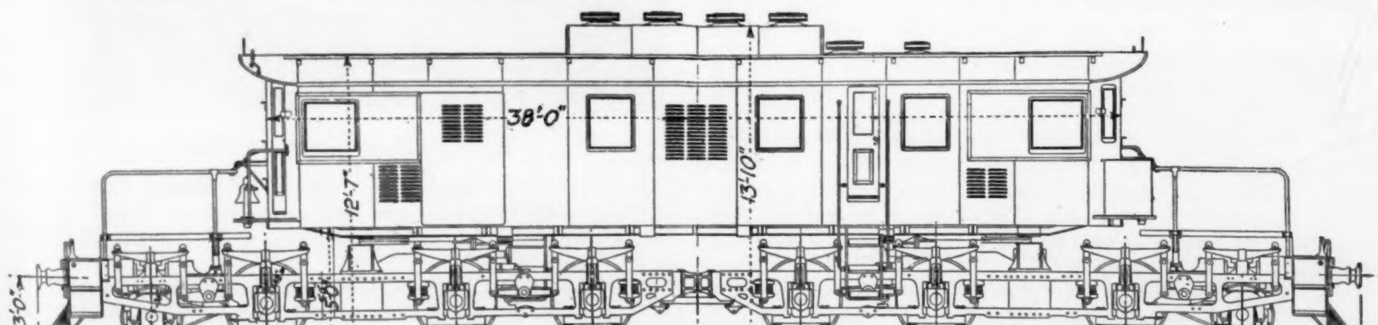

Fig. 4 Chilean State Passenger Express Locomotive

These motors are the largest single-phase motors that have been built in this country. They have eighteen poles and are designed for a speed range of from 23 to 35 m.p.h.

The weight efficiency of this locomotive is exceptionally high. The total is only about 200 tons, which is about evenly divided between the mechanical parts and the equipment.

Two of these locomotives are to be used with direct-current control equipment in the Pennsylvania Terminal in New York, where they will be operated in passenger service.

The Motor-Generator Type of Locomotive

Another type of locomotive which has been discussed more or less in the last few months is the motor-generator type, which it

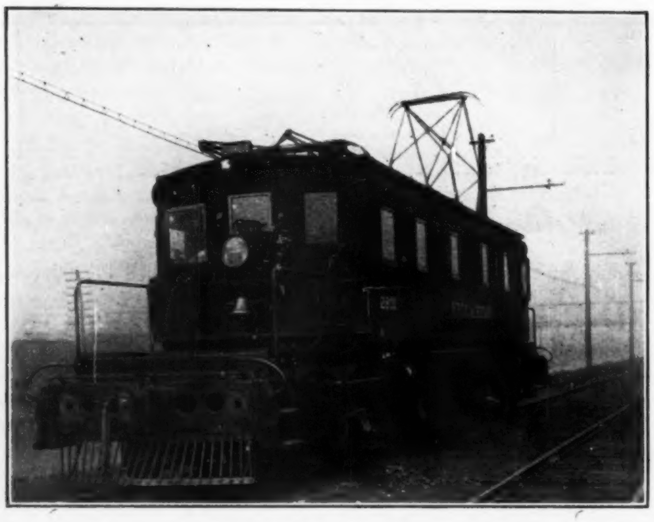

Fig. 5 Chilean State Passenger Locomotive

Fig. 6 New York, New Haven and Hartford Locomotive

was announced some time ago was being built by the Ford Motor Company for the electrification of the D. & I. Railway. This locomotive will operate under a 22,000-volt, single-phase, 25-cycle trolley, but will utilize the current in a different way from any of the foregoing locomotives. The locomotive will have an oil transformer which will reduce the voltage to a low value for a synchronous motor which drives a direct-current generator. This generator will furnish current for direct-current motors mounted on the axle of the locomotive.

This is a most interesting announcement, as it revives the motor-generator idea which was proposed a good many years ago but was never used except in one or two very small locomotives. The reason for adopting this now is that recent developments in machine design have made it possible to design a motor-generator set of sufficient capacity for heavy locomotives without excessive weight or dimensions. The control of a motor-generator type of locomotive is ideal, as all of the motors may be connected permanently in parallel and supplied with current from the generator at any desired voltage. The control of the motor fields will permit the locomotive to develop its full horsepower rating over a wide range in speed and thus to secure one of the excellent characteristics of the steam locomotive.

It may appear at first thought that a motor-generator type of locomotive is simply a direct-current locomotive with transformer and motor-generator set added. Such is not the case. The motors, themselves will be smaller and more rugged than high-voltage direct-current motors, since they may be wound for low voltage and operated on an ungrounded circuit which is individual to the locomotive. The control is extremely simple, since there will be neither series-parallel switches nor starting resistances necessary. This reduces the amount of control apparatus very greatly and thus not only reduces the weight, but the cost of the equipment.

While none of these locomotives has been completed, the indications are that this type of locomotive will have an important place on alternating-current railways.

Discussion

It will be noted that in the list of locomotives that has just been described there are three types of driving motors, several types of mechanical parts, and three distinct types of drive. For all of these differences there are good reasons.

All of the direct-current locomotives listed except the Paulista passenger have axle-hung, direct-geared motors. Axle loadings are limited to approximately 40,000 lb., motors are correspondingly light and speeds are moderate even for the passenger locomotives. For such conditions, the axle-hung, direct-geared motor with flexible

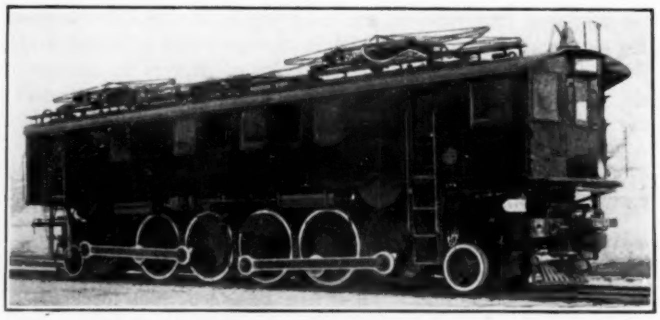

Fig. 7 One Motive-Power Unit, Norfolk and Western Locomotive

Fig. 8 Pennsylvania Locomotive

gears is eminently satisfactory. The direct-current motor lends itself especially to this construction on account of its high weight efficiency and relatively small dimensions, which make it adaptable to any form of drive.

The New Haven alternating-current-direct-current locomotives listed have twin motors and quill-geared spring drive. These locomotives also have comparatively light axle loading, coupled with high speeds. On account of the weight of the motors and the high speed, spring-supported motors were required so the quill-geared type was adopted some years ago and has become the standard of the road. The same motors, quill drive, wheels and axles, are used on their 2–4 + 4–2 passenger locomotives, their 2–4 + 4–2 freight locomotives and the 2–6–2 + 2–6–2 passenger locomotives.

Strange as it may seem, it was found that the use of a twin motor,

i.e., a driving unit consisting of two motors in one frame, with both pinions meshing with the same gear, is more economical than a single motor, for several reasons:

1 The twin motor for this locomotive speed is lighter and cheaper than a single motor of the same output.

2 Only one gear is required for a twin motor, while twin gears are necessary for a single motor.

3 The two sets of armatures and fields of a twin motor are connected permanently in series so as to be equivalent to a motor of twice the voltage and half the current of a single motor. This cuts the sizes of switches and cables to one-half of those required for a single motor.

4 With the motors carried directly above the axles, the twin motors, being of small diameter and mounted side by side, do not extend so far above the floor line of the cab as the single motor and therefore leave much more space in the cab for the control equipment. This is very important where the locomotive is intended for operation on both alternating and direct current.

5 Another advantage of the use of the twin motors on this road is that the electrical design of the individual motor is exactly the same as for the multiple-unit car motors, so that the armatures and other parts are interchangeable.

The latest types of alternating-current locomotives built in this country, both for single-phase commutator-type motors and for induction motors, are those listed in the table for the Pennsylvania and the Norfolk and Western Railroads. Both have the 2–8–2 wheel arrangement and gear and side-rod drive, with the jackshaft located outside of the rigid wheelbase. These locomotives are both designed for the maximum permissible wheel loading, i.e., 75,000 lb. per driving axle. There are very good reasons for adopting gear and side-rod drive for these locomotives. As a matter of fact, a careful analysis will show that it is not only the best but the only type of drive possible for these locomotives after the general arrangement and type of motors and number of axles had been determined.

In the case of the Pennsylvania locomotive, the power required per axle was entirely too great for any single-phase motor that could be geared to an axle. The motor has a continuous rating of 760 hp., at 23 m.p.h. This is the amount of power required for each driving axle. The motor is both too large and too heavy to have one side suspended on the axle and geared to it. The output is too great for a twin motor geared to the quill to develop, as it would require a pair of motors, each having 8 or 10 poles and a quill drive much heavier than any that has yet been attempted to develop the required power.

Motors driving through side rods and jackshaft only would have a prohibitive weight and dimensions so that there was no alternative to gears and side rods, even if this type had not been preferred. As built, the locomotive is wonderfully simple and compact for such a large output. Like all other locomotives built by the Pennsylvania Railroad, it is probably the largest of the type that can be built. The total weight on driving axles of 300,000 lb. is well proportioned to the tractive effort, which is 50,000 lb. continously and 100,000 lb. maximum, as it requires $16^2/_3$ per cent adhesion at continuous rating and $33^1/_3$ per cent at maximum. As it stands, the locomotive is an example of symmetrical design, beautiful lines, and a minimum number of parts for such a large output.

There are other reasons for the use of the 2–8–2 type of locomotive for the Norfolk and Western Railroad. The three-phase induction motor is much smaller for a given output than the single-phase commutator-type motor. An induction motor large enough to develop all the power required for a single axle could have been built and geared directly to the axle, but in this case the four axle-hung motors would have been heavier and would have cost more than the two which were adopted. There is another reason which is still stronger. Induction motors run at an approximately constant speed. They are regulated by liquid rheostats in the secondary circuits of the motors. A separate rheostat is provided for each motor and it is desirable to have an ammeter for each motor in front of the motorman, so he may adjust the loads during acceleration and when there are variations in wheel diameters. Hence, the fewer motors and driving units there are, the less will be the total weight of motors, the simpler and lighter will be the control, and the easier it will be to balance the loads on the motors. Where induction driving motors are used, therefore, practically everything is in favor of using the smallest number of motors possible and this naturally leads to the use of side rods.

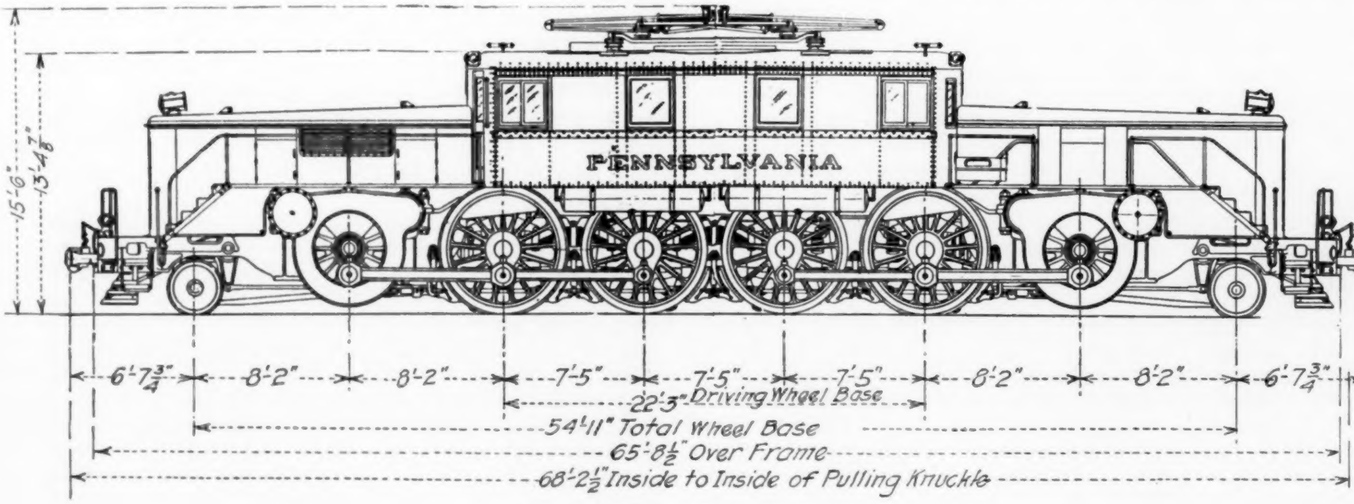

Fig. 9 Pennsylvania Locomotive

Considerations of Type of Drive

It will be seen from the foregoing that there are good reasons for the selection of the type of drive for all of the locomotives in the list.

In general, it may be stated that the choice of drive and the wheel arrangement, which together practically determine the entire design, will depend, first, on the class of service, i.e., whether it is freight or passenger, slow, medium or fast, light or heavy, the permissible wheel loading, track alignment, etc.; second, on the kind of driving motor that is to be used, i.e., whether direct-current, single-phase commutator-type, or three-phase induction; and third, on the judgment of the engineers who direct the design.

It is taken for granted that everyone is striving to secure a locomotive that will in the last analysis show the greatest economy in operation; i.e., one which will give the lowest total cost per ton-mile. It seems to be natural for everyone to assume that a locomotive that has the maximum power concentrated in a single unit on the minimum number of driving wheels will necessarily produce this result. That this is true in the case of the steam locomotive, the author has no desire to question, but he believes that the electric locomotive introduces factors that make it necessary seriously to consider this point in each case. One of the principal reasons for the use of the maximum size of locomotive with a steam engine has no application at all on the electric locomotive. That is the cost of engine crews, since by the use of multiple unit

control it is everyday practice for one crew to handle as many motive-power units as can be desired at one point in the train. Where a very heavy locomotive is required, the capacity of motive-power units should therefore be selected from the points of view of convenience, first cost, and operating cost, with due consideration to the effect on track and bridges.

One of the first points to be settled which is dependent directly on the service required of the locomotive is the total tractive effort which is required under maximum conditions. This ordinarily will determine the total required weight on the drivers.

The next question is the number of driving axles. This will be limited by the permissible axle loading, but will also depend somewhat on the permissible wheelbase and the type of drive which is preferred; also on the most economical size and number of motors to be used. The question of guiding trucks will depend largely on the class of service for which the locomotive is to be used, the length of rigid wheelbase and the speed of operation.

Since the locomotive is composed of so many different elements, it is obvious that no one feature should control the entire design if it is going to handicap the other elements by so doing. For instance, if a certain mechanical design is a handicap to the motors, it should be avoided if possible. Conversely, if a certain type or size of motor is a great handicap to the mechanical design, it should be avoided. The final design should be the best compromise of all the conflicting elements that can be secured.

It is desirable to have all parts that are subject to rapid wear easily accessible for inspection and replacement. It is particularly desirable to avoid crowding, which makes it difficult to remove any piece that is to be overhauled.

Careful consideration should be given to the relative economy of the maximum weight per driving axle with the largest size of motors compared to more motors and lighter axle loading; also to the relative ease of overhauling and the facilities required.

The author appreciates that there are not yet sufficient data available to make anything more than a few general statements in regard to these points, but he feels that the subject is one of such importance that it should be very carefully studied. The very active interest that is now aroused in railway electrification will naturally result in further engineering analysis of this subject, so that during the next few years many conclusions may be developed.

In conclusion, the tendency in heavy locomotive design for freight use seems to be toward the use of maximum axle loadings and transmission by gears, jackshaft, and side rod from motor to axles, together with the combination of the cab with the side frames. There is also a noticeable tendency towards the use of the individual drive with spring-mounted motors for higher-speed locomotives of large capacity. For locomotives with small capacity and axle loading with direct-current motors, the axle-hung motor certainly has the field.

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Relation of the Motor Vehicle to the Railways

By SIR HENRY WORTH THORNTON[1]

IT MUST BE quite clear that the motor vehicle, so far as it affects the railway, may be considered from two standpoints: (1) as a passenger facility and (2) as a freight facility.

As a passenger facility it of course has to be judged by the ordinary standards the public is accustomed to apply to passenger accommodation, namely: (1) its ability to render regular, comfortable, safe, adequate, and satisfactory service as efficiently as possible under all ordinary conditions; and (2) the cost of the service.

There does not appear to be any doubt but that the motor vehicle might quite reasonably be expected to fulfil these conditions in regard to a certain limited class of passenger traffic, particularly on branch lines and in large terminals, thereby supplementing the existing railway passenger accommodation and, in some cases, permitting the railways to eliminate altogether or at least reduce the volume of non-remunerative passenger service.

From the standpoint of the transportation of freight, however, adjustment of the motor truck bids fair to develop into a factor of some considerable importance in dealing with certain classes of traffic, for example: (1) the haulage of commodities from the farm to the railroad or water shipping point; (2) the use of the motor truck in relieving congested terminal conditions; (3) the use of the motor truck in radial operations from large cities in the delivery of less-than-carload lots of merchandise and raw materials; (4) in the haulage of perishable farm and dairy products, such as milk, fruit, and vegetables; (5) in the operation in short hauls between centers of population, where the truck offers a special degree of service in the carriage of commodities from the consignor to the store door or home of the consignee, where time is an important factor; and (6) in longer hauls where rail development has not been sufficiently extensive.

In Canada, as in England, store-door delivery has been adopted as a solution of the problem of freight-house congestion and for a long time carriers have provided in the principal distributing centers a cartage, or a trucking service, between their freight-terminals and the warehouses or store doors of the "traders."

We have not as yet made any experiments in the way of replacing our existing way-freight services by the utilization of the motor truck operating on highways. We have, however, been watching with considerable interest the development along these lines made by private individuals in conjunction with the movement of supplies for limited distances to and from manufacturing plants and by private trucking concerns. We are also utilizing the motor truck in some of our larger terminals for the transfer of L.C.L. freight to and from connections and between freight sheds. This practice has so far proved both satisfactory and economical.

In addition to this, we have been experimenting with various types of self-propelled rail unit cars, largely for passenger and baggage or express services, to meet one or another of the following conditions: (1) to give a frequent passenger service on sparsely settled branch lines, or parts of main line adjacent to market towns or junction points; (2) to connect junction points, on important main lines, with the town or small city situated within a few miles of the main line; (3) to give a group of towns, situated on a main line or important branch line, a frequent connecting service over and above through main-line trains; (4) to connect small summer resorts, golf clubs, etc., to branch-line or through main-line service; (5) to handle milk of a limited amount to a distributing or connecting point; (6) to provide connections to small suburbs.

Motor-propelled vehicles promise to become economical adjuncts to the services performed by railway companies, both on their own lines and on the highways, and an important and a useful field exists for further investigation in this direction.

The attitude of the railway companies toward motor transportation as it is generally and broadly known should not be hostile, but an effort should be made to harmonize both with the object of providing to the community a constantly improving transportation service.

The constantly increasing volume and weight of motor vehicles traveling upon the highway demands a roadbed of more permanent character and provision of some form of assessment in some measure proportionate to the use made of the highway.

Since motor transport is likely to play a constantly increasing part in the welfare and economic life of the community, companies engaged in the industry will sooner or later have to contemplate the same degree of regulation with respect to services and charges as is now imposed upon other common carriers. (Abstract of a paper read at the World Motor Transport Congress, Detroit, Mich., May 21, and published in *Railway Age*, vol. 77, no. 1, July 5, 1924, p. 30.)

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Standardization Versus Individuality

A Word of Caution Against the Too Eager Adoption of Ill-Advised Standards

By LUTHER D. BURLINGAME,[1] PROVIDENCE, R. I.

IN THE baccalaureate sermon delivered by Dr. W. H. P. Faunce, President of Brown University, June, 1924, the speaker deplored any tendency toward standardization in the training of the student body, and emphasized the importance of individuality. He pointed out that standardization typified a "drab," monotonous level in life, but that individuality stands for variety, invention, and progress.

Herbert Hoover, in his campaign for the elimination of waste in industry, urges the importance of standardization, including reduction of the varieties and sizes of manufactured articles, in the interests of efficiency and economy.

Much can be said in favor of each point of view, depending on the interpretation. In dealing with standardization, as with many other important issues, the best and safest course may be a middle ground, reached by carefully feeling the way toward standardization, where it seems most definitely called for, but guarding against the abandonment of basic standards and established practices until the benefits of a change are evident.

An illustration of both these points of view—the importance of individuality urging for change and improvement, on the one hand, and standardization holding to uniformity and resisting change, on the other—is shown in the standardization of car couplings. If the standardization of couplings in the old cars operated by hand brakes had barred innovations, the adoption of the air brake would have been retarded or prevented. Since the restandardization of car couplings in conjunction with the air brake there have been hundreds of patents for improved couplings, not interchangeable with the established standard, which, if adopted, would bring confusion and inefficient service. This is true even though some of the new devices may have merit, and be such that if no standard existed their use would be an improvement over those already adopted. In the first case the breaking away from established standards was in the line of progress and economically sound; in the second case, holding to the established standard against the pressure for supposed improvement appears to be fully justified.

Standardization in the machine-tool industry is confronted with this same problem, and the decision must be made between the two courses: efforts to improve and excel by novelty in design on the one hand, and standardization on the other.

Spindle Noses

To illustrate: The efforts to improve and excel have brought out a number of designs of machine spindle noses, and their cooperating holding devices. These will not interchange with old designs or with each other, and we are challenged with the question, "Which is more important, standardization of design or the continuation of the struggle for the best?"

It is certainly of great importance that old and new machines, the product of a single manufacturer, and that machines of a given size and of the same type of all manufacturers, should be designed with interchangeable spindle noses. Yet if this consideration had been given determining weight a number of years ago when taper-nose interlocking drives were substituted for spindles with threaded ends, as used on heavy milling machines in the earlier days, the holding to such standardization would have retarded progress.

This progress has been along varying lines to the extent that the spindle noses of prominent makers are not interchangeable with each other, interchangeability being even guarded against by patent protection. Points of advantage are claimed for each of the varied designs, and the user, while being challenged to show his preference, is for the time being seriously handicapped in using his tool equipment on the various types of machines he has, old and new.

Without doubt we should look forward to the time when all milling-machine spindle noses will be standardized so as to be interchangeable among machines of a given size, regardless of the make.

Has that time now come? Would it have been possible to have done it when first breaking away from the threaded nose? If several different designs are of practically equal efficiency, who is to decide which manufacturer shall throw overboard his design at great financial loss and perhaps a loss of *prestige* also, and adopt that of a competitor? How are patent interests to be adjusted? These are only a few of the questions which will vex any committee endeavoring to bring about standardization, and when it is done some sufficiently important new method of holding may upset it all.

Spindle Tapers

In the case of spindle tapers there are two well-established standards long in use, and to change either or both in order to bring about a single standard would, it is believed, be a step backward, as far as efficiency is concerned. Two important reasons for continuing these different standards even at the sacrifice of uniformity are: first, the maintaining of interchangeability with past product; and second, providing a standard best suited to each need, a steeper taper being better where the nature of the work tends to force the taper in more tightly as in lathes and drill presses, while a lesser taper gives more "bite" and is better for a class of machines, like milling and gear-cutting machines, where the tendency may be to work or jar loose in the taper.

Tee Slots

Another problem now under consideration is the standardization of tee slots. Here, as in the case of tapers, past use has been so extensive that any change might involve confusion and variation such as to offset the advantage of bringing all to a common standard. On the other hand, uniformity in width of tee slots is an end greatly to be desired, and it is yet to be decided as to whether a break with the past is practical or whether there may be some "bridge" which can connect the practice of the past with some proposed new standard, still preserving at least a degree of interchangeability.

Scope of Standardization

Unfortunately standardization in the past has often been conducted in a limited field, so that when wider uses are developed there are limitations which prevent such standardization being as adaptable as might have been the case if a comprehensive view of the whole field could have been had at the time of adoption. Even with the correlation of interests through the American Engineering Standards Committee and its policy to appoint members representing producers, users, and the public, it is difficult to insure that all interests are given full consideration. After the early work of the National Screw Thread Commission it was found that the interests of the tap makers needed further consideration; and the same can be said regarding the failure to consult interested authorities concerning the standards for fire-hose couplings during the preliminary stages.

A committee appointed to standardize shafting submits a report including the standardization of keys for shafting which may not take into consideration the standardization of keys for general machine work or for other uses. There may be no good reason why the same key standard should not be used for these other purposes, but when once established for the limited field of shafting, it may mean the necessity of adjusting at a disadvantage to use the established standard for other purposes, or the adoption of a separate standard suited to the needs when a comprehensive study of the whole situation might have produced a standard to suit both.

Screw-Thread Standards

Before the time of the consideration of general standardization, the Society of Automotive Engineers adopted a fine screw thread

[1] Indus. Supt., Brown & Sharpe Mfg. Co. Mem. A.S.M.E.

Contributed by the Machine-Shop Division of the A.S.M.E. for presentation at the Machine-Tool Meeting, New Haven, Conn., Sept. 15–18, 1924.

which has become widely used, and now serves as the foundation for the fine-thread series adopted by the National Screw Thread Commission and endorsed by the joint committee under the sponsorship of the American Engineering Standards Committee.

It is possible that if at the time of its consideration there had been a realization of the importance of this standard for general use with machinery and tools and later for airplanes and this had been followed up with the thought of international standardization with the British Empire, there could have been one uniform standard for fine threads suited to all. After this had been established by the S.A.E., however, it was the line of least resistance to take what had already been established and make the best of it for other purposes. There is an illustration of this in the Brown & Sharpe practice where, in manufacturing the Willcox & Gibbs sewing machine back in the 50's, standards were established for small screws suited to this use. These were carefully proportioned for the particular needs, and later, as the line of machine tools and machinists' tools developed, it was natural to use these standards already established for the small screws required on the other products. In the seventy years since that time, tens and perhaps hundreds of millions of such screws have been required from time to time not only for a new product but also for repairs or changes. It can readily be seen what confusion would result from breaking away from these established standards and adopting some different standard, and the question must be answered in the future as to whether (and if so, when) some other standard shall become sufficiently established to justify such a change, involving not only the manufacturer but also the user of the product.

Standardization between Britain and America

As years have gone on it has become more important that America and the British Empire, the great manufacturing and commercial nations of the world, should agree on the question of screw threads. The coarse-thread series at the present time is so nearly uniform in the two countries that it allows of emergency interchangeability, except in the case of the half-inch size, where the British standard is 12 threads to the inch and the U. S. standard is 13. If the slight difference in angle could be made uniform by the British standard's being changed to our 60-deg. angle, and if we would accept the British standard of 12 threads to the inch for the half-inch size, the majority of the screw-thread product of the world—which has been estimated at 80 per cent—would become fully interchangeable, as the question of rounding the crest and root of the thread could be optional without affecting interchangeability. The fact that the British Whitworth thread is coming into more extensive use on the Continent in metric countries makes it important that such agreement shall be at the earliest possible date, if at all. While the immense difficulty of bringing this about is appreciated, it seems within the range of possibility.

Work of Screw Thread Commission and Committees

The extensive and comprehensive work on screw-thread standardization which has been done by committees in America during the last twelve years, should do much to bring about full and real interchangeability in sizes made to our own U. S. standards, ostensibly interchangeable, but which in the past have been found not to be so. Our own difficulty has been much that which was shown when the National Screw Thread Commission visited Europe in 1919, and on making investigations in Paris found that a number of samples purchased at random in that city, and purporting to be made to the metric standard, were not interchangeable.

A serious situation regarding screw threads in America is in the lack of interchangeability in fire-hose couplings. It is reported that three-quarters of the cities of the United States do not have interchangeable couplings, a situation which has in the past prevented assistance from neighboring cities being given when fires have got beyond local control and developed into extensive conflagrations. This is a case where every argument is in favor of standardization as against novelty and variation.

Ball and Roller Bearings

It is often said that standardization originates in, and is spread from, the country or line of manufacture where it is first established and most extensively developed. A curious example of this is found in ball and roller bearings. Development to a certain extent in America, where methods of producing and grinding the balls were perfected, has led to the firm establishment of the diameter of the balls and rollers on the inch system, while the fact that in Germany and Sweden there was an extensive development in the manufacture of complete ball-bearing units for the market, led to proportioning some of the general dimensions in metric units. This has led to a certain degree of standardization on both the inch and the millimeter system, the former predominating for the balls and rollers themselves, while the metric system has encroached somewhat in the standardization of the ball races and casings.

Gear Standards

Another important line of standardization is in the teeth of gears, worms and wheels, sprockets, etc. A forward step in gear standardization was taken by an earlier generation in providing for an interchange of gears in sets, so that any gear from a 12-tooth pinion to a rack would be theoretically correct in engaging any other gear in the set. This had to run the gauntlet of rivalry between the epicycloidal and involute systems, when for years the two systems were in existence side by side and not interchangeable with each other. Since the practical elimination of the epicycloidal system, at least for interchangeable sets, other questions affecting interchangeability, such as pressure angle, height of teeth, etc., have come up for consideration, and there are those today who advocate the breaking away from the established standard and adopting something different which will not be interchangeable therewith because of supposed advantage. If the answer to the challenge, "Is any other proposed system better for general purposes than that now in use?" is in the negative, then no further steps toward a change need be taken. If, on the other hand, the answer is in the affirmative, the question still must be raised as to whether such a system is enough better to warrant breaking away from the world-wide standardization which we now enjoy for the sake of some future gain, the degree of which it is difficult to measure.

Consistent Machine Design

Often in designs of a few generations ago, variation was shown because of originality in the style of knobs, levers, and other operating parts of machines, not only in the product of the same manufacturer but on the same machine. Sometimes an oval section would be used side by side with tee-sections when no good reason for the variation existed. Consistency of design is the criterion, but there are sometimes important reasons sufficient to offset this rule. An instance comes to mind where two operating levers on the side of a machine were so located that the wrong lever might accidentally be operated if the workman reached for it without looking. Making these levers entirely different in shape proved a safeguard, even though it violated all rules of standardization.

Tolerances and Limits for Bearings

Another case is that of the work of the Committee on Tolerances and Limits for Plain Bearings. This, as did the screw-thread question, developed a difference of opinion in practice as to whether a bilateral or unilateral system should become the basis of standardization. It has been found that American practice has leaned to the unilateral, although there are certain very important exceptions where the bilateral is strongly adhered to, while the English practice has been more confined in the past to the bilateral, with a recent tendency toward the unilateral. In this, as in many other cases, the most important consideration is that there shall be a common basis so that all may work alike, rather than that either plan has inherent advantages which the other does not possess.

Wrench Standards

Standardization of wrenches and standard sizes of wrench-head bolts and nuts are questions already before the mechanical public in the report of a sub-committee. In the B. & S. practice, where many varied parts requiring wrench adjustment are often found on the same machine, it has been a problem given careful study to use the fewest wrenches to serve the needs and to adapt wrench-operated parts to these, even if in some cases it required special design. On the other hand, a long step toward securing

(*Continued on page 538*)

Comparative Methods of Tool Design

In Relation to the Quantity Production of Sheet-Metal Parts

By D. H. CHASON,[1] ELIZABETHPORT, N. J.

THE continued demand for economy in manufacturing, resulting from keen competition in the metal industries, and especially in the sheet-metal branch, which has developed by leaps and bounds during the past ten years or so, has placed the pressed-metal industry at the top in quantity production of automobiles, office furniture, cash registers, typewriters, adding machines, bedroom furniture in complete sets, household utensils, sewing machines, toys, partitions and doors for office buildings, electrical goods, and many other articles too numerous to mention. Figs. 1 to 4 show examples of small parts formed by cold swaging and embossing dies.

The object of this paper being to deal with production of sheet-metal parts, no details of punch and die construction will be advanced, but the various types of dies will be mentioned.

The question of proper tools is necessarily of prime importance in meeting production problems. Ordinarily quantity is the most important factor, and quality is the next. There are more ways of designing tools and machinery for sheet-metal work than in any other branch of the metal industries, and often some part which is to be made of sheet metal presents a unique problem in itself, as the possible wide variations in equipment design may involve a number of different methods of manufacture of the same part. Dies play a big part in keeping down selling-prices to a minimum on automobiles and many other articles. There are many kinds of dies, as blanking, bending, drawing, combination blanking and drawing, compound, progressive or follow dies, shaving, trimming, gang or multiple dies, double- and triple-action forming dies, curling, subpress, swaging, embossing, piercing, coining, redrawing, notching, shearing, dinking, heading, riveting, staking and extruding dies—or combinations of any of these types. Different methods of construction are possible with any of these dies, and this is where quantity and quality of product enter into the matter.

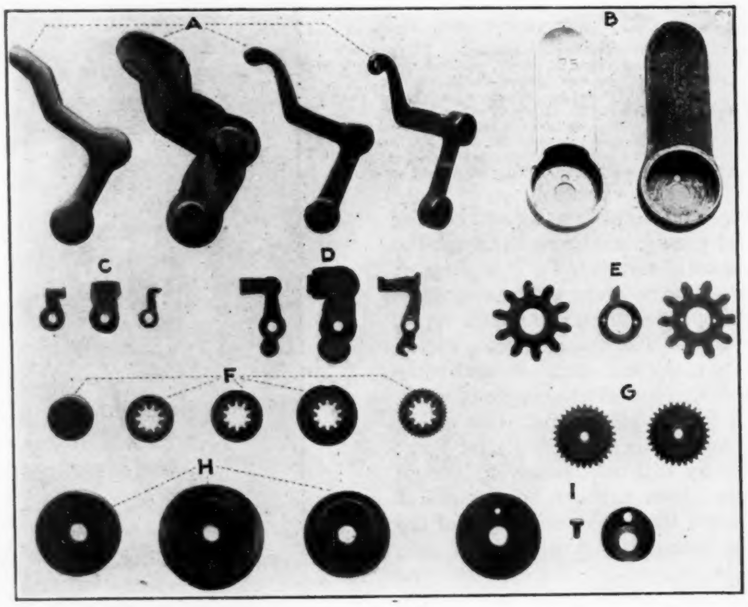

Fig. 1 Examples of Cold Swaging

A, Formerly drop forged and machined all over; now cold swaged. *B*, formerly drop forged; now cold swaged. *C* and *D*, cold swaged. *E*, formerly two punchings held together by two rivets; now cold swaged in one piece. *F*, formerly blanked on screw machine, internal teeth broached by hand, and single tooth milled in special fixture; now made completely by cold swaging. *G*, formerly three punchings and screw-machined hub, held together by three rivets; now cold swaged in one piece. *H* and *I*, each formerly two punchings (teeth milled) held together by screw; now cold swaged in one piece (teeth punched).

Effect of Quantity and Tolerance on Choice of Die

The speed of the power press being used is generally governed by the nature and thickness of the stock, as well as the surface size of the blank being produced and the number of operations necessary. Consider, for instance, a plain washer $^1/_2$ in. in diameter, with a $^1/_8$-in. hole, being made of stock $^1/_{32}$ in. thick.

Example 1. Required: only 5000 blanks, which is a very small total for a press job. In this case a very simple punch and die are to be considered, the usual progressive or follow die, the punch being held in the press ram and the die on a shoe fastened to the bolster of the press. With such an equipment the 5000 blanks could be produced in one hour's work on the press, including time for setting the die. This arrangement would rank as a makeshift or temporary tooling, which would be built as cheaply as possible, particularly if the tools were not intended for any further use.

Example 2. Supposing the same $^1/_2$-in. washer to be required in large quantities, say millions. A suitable equipment would then be a multiple progressive die, mounted on a pillar-type subpress, the upper member of the subpress being connected by a loose connection to the press ram. The number of blanks obtainable at one stroke depends of course upon the width of the stock and the size of the press. A double roll feed on the press forms a good combination with this type of die, especially should the stock used come in coils instead of flat strips. An outfit as described would produce from 25,000 to 100,000 pieces per hour, depending upon the number of blanking holes in the die and the press size.

Example 3. The same washer, required within very close limits, say, plus or minus $^1/_4$-thousandth in. (0.00025 in.) on outside diameter and hole size. Here the same number of multiples can be used as in the regular progressive or follow die, but the die construction would be of the type known as compound, in which the die proper is mounted on the upper member of the subpress, while the punch is fastened to the lower member. This type of die pierces the holes and punches the outer shape simultaneously. An inclinable press with a ram knockout and double roll feed would make a good equipment in this case, although such a die can run without a positive knockout in the ram by using springs in back of the shedders. However, the positive knockout used in connection with these springs assures a positive ejection of the blanks from the die. An equipment as outlined, fitted with air for blowing the blank from the strippers on the punches, performs very satisfactorily.

Subpress Dies

While generalizing on production, there is no factor better worth mention than the pillar-type subpress. This subject may be briefly dealt with, by way of emphasizing the importance of the subpress in production work, especially on interchangeable parts.

It would seem that the subpress, as an adjunct of the power press, has not found the extensive use which it truly merits. It can be used in connection with any of the various dies before mentioned; in fact, for all the variety of work generally done on power presses. The main reason for its restricted use may be the initial cost, especially where the cylinder-type subpress is involved. However, investigation will show that a properly made subpress will considerably increase the life of the punch and die. The extra cost will soon be made up in the setting-up time saved, and in the smaller amount of grinding necessary to keep the punch and die in proper condition. In some respects a power press is the most-abused machine in the shop, and this is probably due to a lack of knowledge

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Contributed by the Machine Shop Division of the A.S.M.E. for presentation at the Machine-Tool Meeting, New Haven, Conn., Sept. 15–18, 1924.

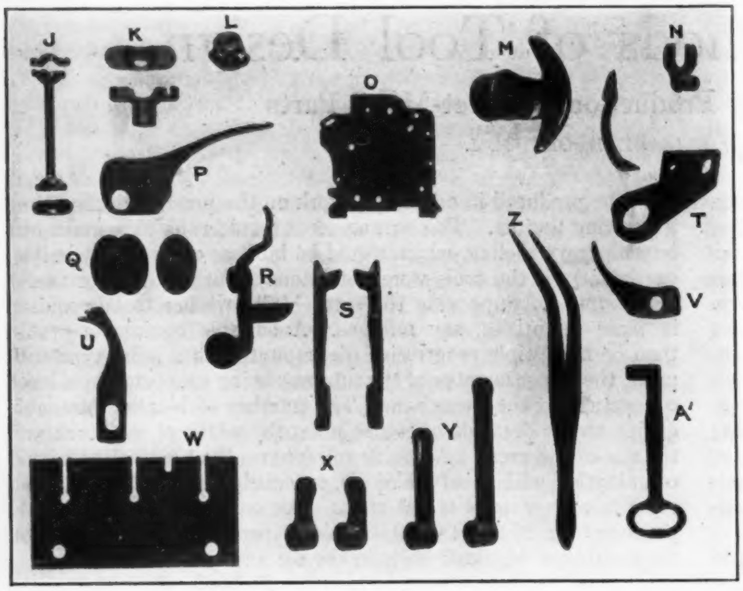

FIG. 2 EXAMPLES OF COLD SWAGING

(*J*, *K*, *L*, formerly drop forgings machined all over; now cold swaged. *M*, formerly drop forging machined all over; now made of cold-swaged hook, welded to screw-machined hub. *N*, cold swaged. *O*, very accurate piercing operation mentioned in text. *P*, formerly machined; now cold swaged. *Q*, formerly made on screw machine; now made of two parts formed on press and welded together. *R*, formerly drop forged; now cold swaged. *S* and *T*, cold swaged. *U* and *V*, formerly made by machining operations; now cold swaged. *W*, slots formerly milled; now cold swaged. *X* and *Y*, formerly drop forged; now cold swaged. *Z*, formerly filed to shape and riveted together; now cold swaged to shape and spot welded. *A′*, formerly malleable casting; now cold swaged.)

concerning the provision of a proper means of locating and holding the punch and die. Many a good press is condemned through the use of poorly designed and constructed members for this purpose, which is particularly true of the subpress, and may in a measure account for its restricted use. Subpresses are made in two types, the cylinder type and the pillar type. The cylinder type, Fig. 5, is the older and more expensive to make and maintain, and while it may have some advantages in design for certain classes of work, it has been generally superseded by the pillar type. One of the advantages claimed for the cylinder type is adjustability for wear; this advantage being more imaginary than real, however, because if the wear on the plunger has not been uniform, adjustment of the aligning bushing may not restore the proper alignment of the punch and die, which may both be damaged if not ruined as a result. Another advantage which may be claimed for the cylinder-type subpress is compactness; but this very compactness restricts the die space. Pillar subpresses, Fig. 6, are cheaper and simpler to make than the cylinder type, and have the distinct advantage of more die space. It may be claimed that the pillar type lacks adjustability for wear, but this is not true of properly designed pillar subpresses. The subpress itself may be excellently made, but if its upper and lower members are improperly fastened to the power press, the excellence of the subpress and the power press goes for naught. The old-time general practice in this regard was to fasten the upper subpress member rigidly to the ram of the power press, as in Figs. 7 and 8, and the lower member rigidly to its bed, or bolster.

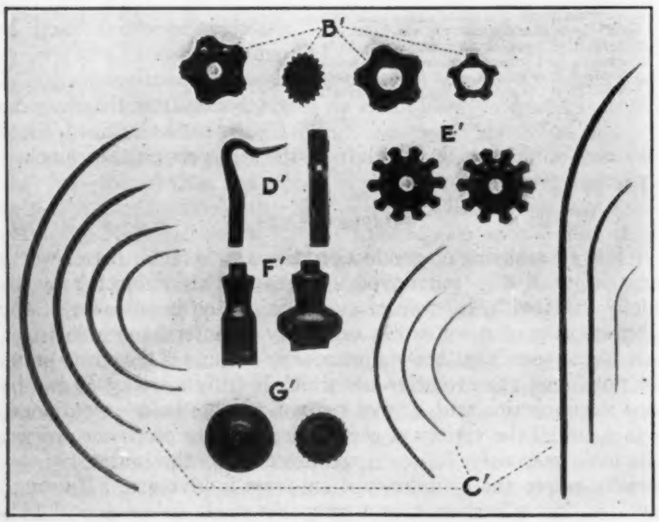

FIG. 3 EXAMPLES OF COLD SWAGING

(*B′*, formerly two punchings and one screw-machined part, assembled with two rivets; now cold swaged in one piece. *C′*, surgical needles; all cold-swaged. *D′*, formerly machined to shape; now cold swaged. *E′*, formerly three punchings assembled with two rivets; now cold swaged in one piece. *F′* and *G′*, now cold swaged.)

FLOATING CONNECTION

When the plunger of a cylinder-type, or the upper member of a pillar-type subpress, is rigidly connected to the press ram,

FIG. 4 EXAMPLE OF WORK DONE IN A KNUCKLE-JOINT EMBOSSING PRESS
(Formerly engraved and subsequently embossed in hydraulic press.)

the subpress loses its true character as such. The reason and sole function of the pillars in a pillar-type subpress, or the bearing around the cylinder in a cylinder type, is to do the guiding. If, therefore, the upper member is fastened rigidly to the power-press ram, this function is impaired or destroyed. It may be argued that a rigid connection here gives the assistance of the ram to the pillars of the subpress for guiding purposes, but this is true only where the press ram and upper subpress member are in perfect alignment, a condition that is hard to attain, and harder to maintain. It has been observed in a number of power presses where the rigid subpress connection was used, that the pillar holes were worn elongated from the continuous cramping action on the pillar, and in some cases where a shank or plug connection was used, the shank was shorn off. On the other hand, on a pillar subpress having an adapter with $^1/_{32}$ in. or more of play, in other words a floating connection, it was found that the pillar holes were but 0.002 in. larger than the pillars, this being an instance in which the press had been in almost continuous operation for 10 years. Therefore it seems to follow that a floating connection is preferable to the rigid in mounting subpresses, and that the subpress pillars alone should be relied

on for guiding, which is their sole purpose. It may be said that a floating connection is as essential for a subpress as for a floating reamer in a screw machine, with accuracy the object.

Fig. 9 shows several kinds of the pillar-type subpresses, which are distinguished mainly by the location of the pillars in relation to the punch and die, and the style of connection to the press ram. In locating the pillars, it is best to bring them in line with the punch and die centers. This will obviate any tilting or cramping action on the pillars by the upper member.

In many factories where the equipment consists of old-style presses, there is insufficient space between rams and beds for subpresses. In such cases the bed and the ram may be planed off enough to make the necessary room, or clearance holes may be drilled in the press ram for the subpress pillars.

Design of Pillar-Type Subpress

For the upper and lower members of a pillar-type subpress, a good grade of charcoal iron should be used. After rough machining, this material should be allowed to season, and the faces should then be machined parallel within limits of 0.0005 in. The pillar holes should not be cored, as better results are obtained by drilling them from the solid. Machine steel is the proper material for the pillars, which are turned, pack hardened, rough ground and

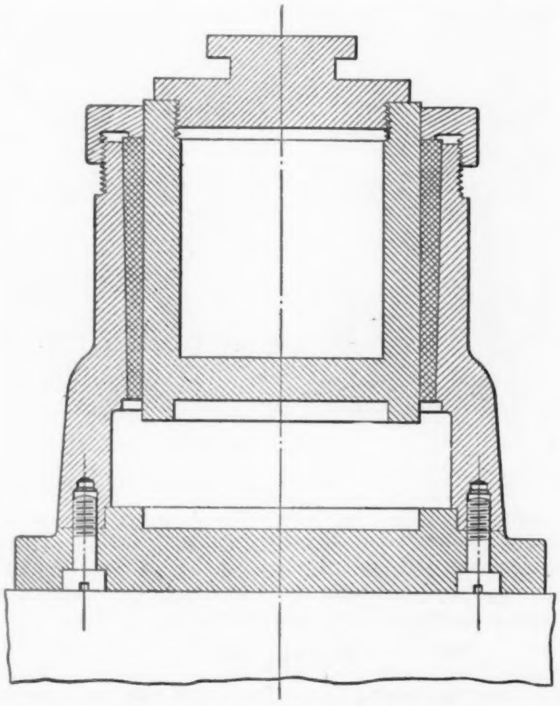

Fig. 5 Cylinder-Type Subpress

seasoned; then finish ground, and lapped to a sliding fit in the upper subpress member, and ground to a driving fit in the lower member. To avoid reversing the pillar in the grinding machine, a hole should be drilled in its end, to engage a pin in the faceplate or pulley of the grinder. By using this method, the pillar may be ground in one setting, thus avoiding making the two bearings eccentric. In some cases, two different-sized pillars are used in the same subpress to prevent improper setting of the punch and die in relation to each other. Where the same-sized pillars are used, some distinguishing mark should be made on the upper and lower subpress members, giving a guide for the proper assembling of the subpress. A good practice is to number both members on the front where the marking will be conspicuous. By using different numbers, the tendency to mix the members of different subpresses will be avoided.

The use of oil grooves on the pillars should be avoided, due to the marked lapping tendency of a grooved pillar, which shortens the life of the bearing. Actual experiments have proven this. Countersinking or beveling the bearing holes on the top of the upper subpress member (to act as oil reservoirs) is found very satisfactory for lubricating the pillars. The use of bushings or liners is unnecessary, as the cast-iron bearings become glazed, and will then outlive any steel or bronze bushings. It is of course essential to have the holes smoothly reamed, and the pillars smoothly ground and lapped.

Care of Subpress

The care of a subpress should not end with its use on the power press. Placing it on the floor under the press, or anywhere else exposed to dirt, is not conducive to its efficiency when again placed in service. After use it should be cleaned and oiled, and placed on a suitable rack, the size of which, of course, depends upon the

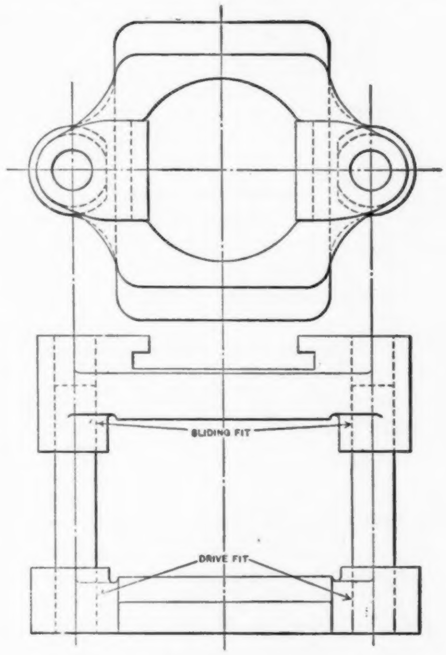

Fig. 6 Pillar-Type Subpress

number of subpresses to provide for. Each subpress should have its own space on the rack, as piling one on top of another is poor practice.

Design of Punches and Dies

Regarding the design of punches and dies, it is always well for the designer of the article to be manufactured to consult the die engineer or designer, as sometimes a slight change in the shape of the piece, or in the location of holes, will render the work a more practical manufacturing proposition, through decreasing the number of operations and increasing the life of the die. Such coöperation will quite often obviate changing over dies which have been laid out to an original sample designed without this procedure. Observation has shown where machines or devices have been designed, embodying many parts designated to be made of iron castings, forgings, metal parts machined from solid stock, etc., which, if first discussed in the manner suggested with a sheet-metal engineer familiar with modern die design, might have been adapted to manufacture from sheet metal, at a considerable saving in cost. Some idea of the wide range of presswork possibilities is given in Figs. 1 to 4. Parts made of sheet metal are often stronger, lighter, and better appearing than if made of other material. Cases have occurred where a component member of some apparatus, consisting of as many as seven distinct parts, could easily have been made in one piece by the cold-swaging method and at much less expense, which in addition would have afforded greater accuracy than would be possible in the assembled unit made up of several pieces.

An important factor in cold-swaging work is to provide sufficient clearance in the die to prevent its confining the stock while under pressure, i.e., space should exist for surplus metal to flow into, forming a fin, to be trimmed off in a subsequent operation, as in drop forging. Those unfamiliar with this work frequently have trouble here, while dies properly built in this respect have longer life.

Feeding Devices

It has been mentioned that a double roll feed is advantageous for blanking work in quantity production. However, this feed is also valuable in conjunction with combination dies, such as blanking, drawing, bending, and piercing dies, as well as dies of special construction to meet particular requirements. The dial feed is also a valuable feature in rapid production, taking blanks in almost any shape, from flat blanks to formed pieces, and adding thereto

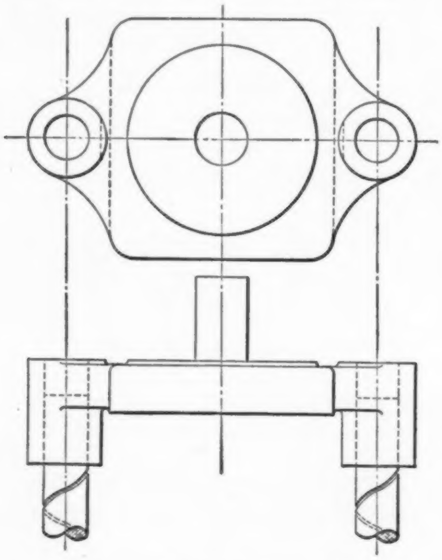

Fig. 7 Upper Member of Subpress Having Usual Type of Shank or Plug Connection

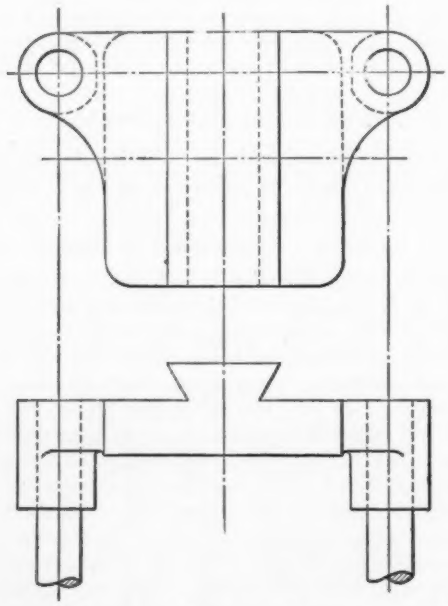

Fig. 8 Upper Member of Subpress Dovetailed to Press Ram

a number of operations to complete the part. Quite often several ways of feeding the blanks into a dial-feed press are possible. They may be inserted by the operator as the dial revolves—or they may be stacked in a magazine, with a slide operated by the action of the press, to place the blanks in the dial. Some parts can be fed into the dial with a hopper feed connected with the magazine and the dial.

Types of Presses

Another machine valuable for rapid production is known as the 4-slide machine, and is used for such operations as piercing, blanking, forming, etc. This type of machine usually works best on flat strip steel, and will produce a part ordinarily requiring about six power-press operations at the rate of 40 to 300 per minute, depending on the size of the part and thickness of material used.

Another type, known as the eyelet machine, is especially valuable for quantity blanking and drawing of round steel shells. These machines will perform as many as ten drawing operations at one stroke, depending on the number of plungers used.

Often cases occur where a special machine can be provided to shorten manufacturing processes simply by eliminating or combining a number of press operations. Of course, such a machine is only warranted by sufficient work to make it pay.

It has been found in many cases that blanking and piercing dies have derived longer life from a speeding-up of the press.

For embossing and coining work, the toggle type of press is recommended. In one case, a knuckle-joint embossing press replaced three hydraulic presses in operation on embossing work, and the life of the dies was thereby doubled. (See Fig. 4.) From this it is evident that the slow action of the hydraulic presses, which exerted a continuous pressure (punishing action) on the dies, tended to break them down much faster than the speedier stroke of the knuckle-joint embossing press.

It is often questioned whether very close limits can be maintained on parts produced in dies. A case may be quoted where it was necessary to pierce a number of differently shaped holes in a small plate about $^3/_{64}$ in. thick, and strict accuracy was required. To check the pieces a gage was provided, having plugs of the sizes

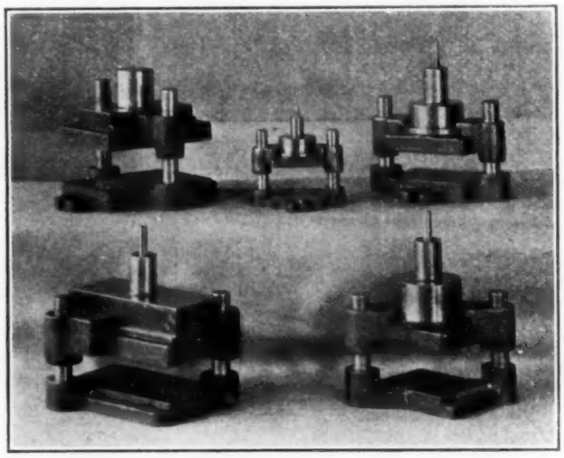

Fig. 9 Pillar-Type Subpress with Floating Connection to Press Ram

and shapes necessary, positioned according to model. This exacting problem was satisfactorily met, as the blanks fitted the gage perfectly; and the same facts apply to many other cases of record. The piece is shown in Fig 2, marked *O*.

Shaving Dies

For accuracy in holding the outside shape, size, and smooth finish of parts, a die known as a shaving die is valuable. The hole in such a die is usually made straight, without any angular clearance, so that it is possible to grind the die without changing the shape of the hole. Frequently such work is milled to shape, a number of blanks being held together in a fixture and finished with form cutters. However, a shaving die will give equally good results as to smoothness of finish, and quite often can be held to closer limits than is possible in a milling cut. For rapid production of this class of work, the pieces can be stacked in a magazine and carried into the die automatically by the action of the press. It is of advantage in using shaving dies to locate the blank on the punch by means of one or two holes in the blank which fit corresponding locating pins on the punch. Of course, in this case the die is above and the punch below, as in compound blanking dies. The advantage of this arrangement is that the scrap falls away below instead of into the die. In this connection, it is well to provide one or two sharp-edged punches or chisels to cut the scrap as it is being forced down over the punch, so that it will readily fall away instead of gathering around the punch. There are other methods of locating blanks in shaving dies, usually dependent upon the shape of the piece. Often a nest is provided on the die, which is made in sections and held together by springs. In this case the die is below

(Continued on page 538)

Shop Measurements

English and Metric Standards of Length and Their Interrelation—Accuracy and Purposes of Shop Measurements

By EARLE BUCKINGHAM,[1] HARTFORD, CONN.

MEASUREMENT implies comparison with some standard. Measurements are the basis of all our exact knowledge. In every line of human endeavor, measurements of one sort or another are the only tests of achievement.

In machine-shop practice, measurement is a fundamental process. The accuracy to which we can work depends upon the accuracy with which we can measure. The removal of material from the part under construction is seldom a difficult task; the critical point is to know when to stop. This can only be determined by measurement.

The science of shop measurements has never been reduced to writing. It has always been part of that vast amount of information and experience which the apprentice must acquire while learning his trade. Most of this information is acquired by observation. The ability to measure is thus usually acquired in a haphazard manner—more as a collection of methods of how to measure various forms and sizes than as a clear understanding of the theory and practice of measurement.

The purpose of this paper is to point out certain fundamental principles of measurement.

Measurements of Length

The majority of shop measurements are reduced to measurements of length. We will therefore confine this discussion to such measurements.

Measurements of length are expressed in terms of some definite unit of length. Fundamentally, such a unit of length is a fixed distance in space. As far as such *abstract* units of length are concerned, the matters of temperature, material, etc., are not involved. It is only when these units are represented physically by some bar of metal that these factors are introduced.

In order for a unit of length to have any practical value it must be definitely established in some manner, either by law or common usage.

From early times the attempt has been made to establish a unit of length in terms of some natural phenomenon, but eventually these units of length were established arbitrarily as the length of a definite metal bar under definite conditions of temperature, etc. For example, at the present time the most widely used units of length are the yard and meter and their subdivisions. The attempt was made to define the yard as the length of a pendulum with a definite period of oscillation. This was found impractical. The attempt was made to define the meter as a definite part of the earth's quadrant, and this also was found impractical. In both cases the size of such a defined unit of length was found to vary as improved and refined methods of making the necessary observations were developed. It is obvious that a fundamental unit of length which is subject to any appreciable variation will create much confusion, and be practically worthless. In both of the foregoing cases the fundamental unit of length was eventually defined as the distance between two lines on specific bars of metal at a specified temperature.

It is of interest to note that at the present time it appears to be possible to define these units of length in terms of light waves. If the primary standards of length were destroyed, they could now be reproduced within a limit of error of one or two parts in a million by such means. At the present time consideration is being given to this method of defining these standards. To the best of our present knowledge, units of length so defined would be more stable than our present physical metal ones.

After a fundamental unit of length has been accepted, it is necessary to adopt some common practice in regard to its application to various types of measuring instruments in order to maintain uniformity among them. A metal measuring instrument can represent a specified abstract length only at one specific temperature. Hence if one bar duplicates the abstract length of a yard at 60 deg. fahr., while another duplicates it at 70 deg. fahr., the two bars when compared with each other while at the same temperature will vary. The bar which is standard at 70 deg. fahr. will be shorter than the one which is standard at 60 deg. fahr. The practice in this respect varies considerably between the English and metric units of length, so that space will be taken to discuss each system in some detail.

English Standards of Length

The fundamental English standard of length of one yard is the distance between two fine lines graved on gold plugs in a bronze bar at Westminister, when this bar is at the temperature of 62 deg. fahr. Copies of this fundamental yard made for general use are calibrated against the original bar, and any observed differences are noted in one of two ways. First, the measured difference between the two bars when both are at 62 deg. fahr. may be given. Second, the temperature of the copy may be varied until both bars are of the same length. Then this second bar is calibrated as having the correct length when at the altered temperature, such as 63 deg. fahr. for example.

When such calibrated bars are used in other comparisons, the necessary correction is made either by compensating for the known difference in length at 62 deg. fahr., or by keeping the calibrated bar at the corrected temperature and the measured bar at its desired temperature of calibration.

Any standard with a definitely known error is practically as good as a perfect one, as such known errors can be compensated for. This is especially true of primary standards which are used to calibrate the industrial measuring instruments, where such calibrations are made in laboratories where the temperature conditions are carefully controlled.

For general industrial uses such extreme refinements are not necessary. As long as the limit of error of measurement is kept well within the probable error of execution in the production of the parts to be measured, industrial measuring instruments are sufficiently accurate.

For purposes of uniformity, it is most desirable that all industrial measuring instruments be nominally of correct size when at some common temperature. Furthermore, as not only these measuring instruments but also parts measured by them may be made of different materials with different coefficients of expansion, it is most desirable that this common temperature be one approximating the average working temperature at which such instruments are ordinarily used.

At the present time two different temperatures at which measuring instruments for English units of length are nominally of correct length, or standard, are used. These temperatures are 62 and 68 deg. fahr.

The temperature of 62 deg. fahr. was originally used because it is the temperature at which the fundamental standard yard bar is of correct length. This temperature is used exclusively in Great Britain.

The temperature of 68 deg. fahr. (20 deg. cent.) is rapidly gaining in favor in the United States because it more nearly represents the average working temperatures; because it has also been widely adopted as a standard temperature for many other physical tests; and because it is exactly equivalent to an even centigrade temperature, 20 deg. This temperature has been used exclusively in the United States for the past ten years in all gage standardization.

Due to this difference in temperature at which measuring instruments are standard, a one-inch part made to a measuring instrument which is standard at 62 deg. fahr. (assuming steel parts with a coefficient of expansion of 0.0000063 in. per deg. fahr.) would

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measure 1.0000378 in. when measured with an instrument which is standard at 68 deg. fahr., while a one-inch part made to a measuring instrument which is standard at 68 deg. fahr. would measure 0.9999622 in. when measured with an instrument which is standard at 62 deg. fahr. This difference of calibration temperature thus makes a difference of about 38 parts in a million in the measured size of the same part. In the majority of cases in machine-shop practice it can be ignored. Where the requirements are exacting, however, it must be compensated for.

Metric Standards of Length

The fundamental metric standard of a length of one meter is the distance between two fine lines graved on a platinum-iridium bar at the International Bureau of Weights and Measures at Sevres, France, when this bar is at the temperature of 0 deg. cent.

Copies of this fundamental meter, of duplicate construction and material, have been made, calibrated against the original, and distributed to the several countries subscribing to the International Bureau of Weights and Measures. These copies are numbered and known as prototype meters. The prototype meters Nos. 21 and 27 are held in this country at the Bureau of Standards at Washington. These bars are nominally of correct length at 0 deg. cent.

For general industrial use at the present time, two different temperatures at which metric measuring instruments are nominally of correct length are used. These temperatures are 0 and 20 deg. cent. (68 deg. fahr.).

The temperature of 0 deg. cent. (32 deg. fahr.) was originally used because it was the temperature at which the fundamental standard meter bar is of correct length; and because this temperature, the melting point of ice, could be duplicated and maintained more nearly exactly than any other. The great difference between this calibration temperature and the ordinary working temperatures at which measuring instruments are used introduces a complication. Instruments made of different materials with varying coefficients of expansion, which would measure alike when at the temperature of 0 deg. cent., would show measurable differences when used at the ordinary working temperatures, because of their differences of expansion. To overcome this difficulty, the director of the International Bureau of Weights and Measures recommended the following practice:

Gages and other measuring instruments used in the manufacture of metal parts should be so made that when calibrated at a temperature of 20 deg. cent. they have an assumed coefficient of expansion of eleven millionths per unit of length per degree centigrade. In other words at 20 deg. cent. the actual length of such standards will be 220 millionths per unit of length longer than the corresponding subdivision of the fundamental standard of the meter at 0 deg. cent.

This recommendation is eminently practical. The majority of measuring instruments used in the metal-working trades are of steel. The coefficients of expansion of cast iron and steel—the most commonly used materials for parts of any appreciable size—vary from about ten to twelve millionths per unit of length per degree centigrade. Thus the temperature of 0 deg. cent. at which the parts nominally have their specified abstract length is maintained closely enough for all practical purposes. On smaller parts made of other materials the theoretical error introduced by this practice is very slight, as it depends upon the difference between their actual coefficient of expansion and the arbitrary one of eleven millionths. For scientific work in laboratories, such differences must be considered, but for all practical purposes in the machine shop they may be ignored. This practice is followed almost exclusively in France.

The temperature of 20 deg. cent. (68 deg. fahr.) is also widely used, particularly outside of France, because it more nearly represents the average working temperature; because it has also been widely adopted as a standard temperature for many other physical tests; and because it is exactly equivalent to an even fahrenheit temperature of 68 deg. This temperature has been adopted as standard for all gages and other industrial measuring instruments by the engineering standardization bodies of Sweden, Holland, Switzerland, and Germany. In this case the lengths of the measuring instruments when at the temperature of 20 deg. cent. are the same as the corresponding subdivision of the fundamental standard of the meter bar at 0 deg. cent.

Due to this difference in temperature at which measuring instruments are standard, a 100-millimeter part made to a measuring instrument which is nominally standard at 0 deg. cent. would measure 100.022 mm. when measured with an instrument which is standard at 20 deg. cent., while a 100-millimeter part made to an instrument which is standard at 20 deg. cent. would measure 99.978 mm. when measured with a measuring instrument which is nominally standard at 0 deg. cent. This difference of calibration temperature makes a difference of 220 parts in a million in the measured size of the same part. This difference is so great—over five times as much as in the similar case of different practices in regard to the yard—that it must be compensated for in any case of high-grade machine-shop work.

It is significant to note the many points of similarity between the yard and meter, and practices employed in using them. The fundamental standard in both cases is arbitrarily defined as the length on a specific bar of metal at a specified temperature. In both cases the country in which the units were originated holds to the same temperature at which measuring instruments are standard as that at which the fundamental bar has its correct length. Alien countries that have adopted either standard, having no sentiment in regard to the matter, accept the abstract units of length, but calibrate their measuring instruments at another temperature.

Interrelation between the Yard and Meter

The absolute relationship between the yard and the meter may never be established. Many comparisons have been made, and results varying from each other by three or four parts in a million have been obtained. At the present time, the legal relationship between the yard and meter in Great Britain is

$$1 \text{ meter} = 39.370113 \text{ inches.}$$

The legal relationship between the yard and meter in the United States is

$$1 \text{ meter} = 39.37 \text{ inches.}$$

The difference between these two relationships is about three parts in a million, a difference so small that it may be neglected entirely as far as machine-shop practice is involved.

It has been proposed that the two foregoing relationships be discarded in favor of the following:

$$1 \text{ inch} = 25.4 \text{ millimeters.}$$

This relationship would make 1 meter = 39.370078 inches, a value between the two previous ones. Any one of these three values is sufficiently accurate for all practical purposes. These figures represent the relationship between the abstract length of the yard and the abstract length of the meter.

If the standard practices in using the yard and the meter were identical, the foregoing relationships would be all that was needed to secure duplicate results by the use of either system of measurement. Considering existing conditions, however, they are incomplete because these practices vary. It has already been pointed out that at the present time there are two different practices in regard to the use of English units of length commonly used, and also two different practices in regard to the use of metric units of length.

This further consideration has nothing to do with the relative abstract lengths of the yard and meter. It is necessary only because of the different temperatures used at which the different measuring instruments have their correct nominal sizes. For example, we will assume that we have to make some parts to metric measurements. We have available measuring instruments to English units of length, and these instruments are standard at 62 deg. fahr. After shipment to France, however, the parts will be checked with metric measuring instruments which are nominally correct at 0 deg. cent. We must make a correction for this difference in temperature. Again, if the parts are sent to Sweden or Holland, or Germany, the parts will be checked with metric measuring instruments which are correct at 20 deg. cent., and we must make a different correction for difference in temperature than before.

Thus we are confronted in actual practice with the four following interrelations, assuming that the correct relation between the abstract lengths of the yard and meter is 1 meter equals 39.37 inches:

1 meter (20 deg. cent.) = 39.37 inches (68 deg. fahr. or 20 deg. cent.)

1 meter (0 deg. cent.) = 39.378661 inches (68 deg. fahr. or 20 deg. cent.)

1 meter (20 deg. cent.) = 39.371444 inches (62 deg. fahr.)

1 meter (0 deg. cent.) = 39.377218 inches (62 deg. fahr.)

These factors are based on an arbitrary coefficient of expansion of eleven millionths per unit of length per degree centigrade.

It is to be hoped that some common international practice in this respect may be adopted in the near future so that these various interrelation factors for actual measurements may be reduced to but one. In the meantime, however, where close measurements are required, it is necessary to know the temperature at which the measured parts in question are to be standard, and act accordingly.

Measurements

In general, shop measurements may be divided into two general classes: direct and comparative. A direct measurement is one where the attempt is made to determine the actual, or abstract, size. A comparative measurement is one where the attempt is made to determine the difference in size between similar or mating parts. In general a comparative measurement is much easier to make than a direct one. With equal care and skill a comparative measurement will always be more accurate than a direct one. Furthermore, differences in size too small to be detected by ordinary direct measurements are readily detected by ordinary comparative ones. For example, if two plug gages within one-quarter of a tenth of a thousandth of the same size were given to several skilled workmen to measure with micrometers, they would all probably report them of identical size, but the measured value would probably vary one- or two-tenths of a thousandth of an inch. These same workmen, however, comparing the two gages with ordinary calipers, will invariable pick out the same large and small ones, although the actual difference in size may be too small for them to measure. Thus where uniformity is essential on any critical dimension of a product, a physical standard or master gage of the size desired is always the simplest and most effective means of maintaining the desired uniformity.

Accuracy

No measurement of a physical quantity is ever correct in an absolute sense. Accuracy is a relative term. For example, an astronomer may make an accurate determination of the position of a star. His measured distance may vary from the actual distance a million miles or more. Nevertheless his determination is accurate. Going to the other extreme, a physicist engaged in making measurements of the length of light waves must have his determination correct to within a very small fraction of a millionth of an inch in order to be accurate.

In machine-shop practice a definite dimension may be specified. When developed in metal we may never get that exact dimension, no matter how many similar parts we make, but a more or less accurate approach to the specified size. Thus on a drawing the dimensions are constants, but in metal the sizes of the several surfaces are variables. If we keep this fact in mind it will do much to clarify the subject of proper dimensioning.

Purposes of Shop Measurements

The purpose of shop measurements is to control the sizes of the parts being manufactured. Every size of every surface is measured in some manner. Many times, on experimental work for example, no attempt is made to hold the various surfaces to any exact predetermined size, but the mating surfaces are fitted to each other. In such cases the first surface finished becomes the measuring instrument for its mating surface.

Shop measurements are essential in all stages of production. Parts made individually are first laid out. This operation is identical in many respects to the layout or drawing made on paper. In the case of a drawing, the measurements are all made in one plane. The layout on the metal parts, however, requires measurements in several planes. The making of all such layouts is essentially a matter of measurement.

As the machining operations progress, measurements must constantly be made. As stated before, the mere removal of material from the part under construction is seldom a difficult task. The essential thing is knowing when to stop.

After that part has been completed, measurements are required to insure that the desired results have been attained. Such measurements may be direct ones, checking their measured dimensions against the specified ones; or they may be comparative ones made by assembling the parts and judging them by the resulting assembled conditions.

Before any shop measurements can be effectively made, three questions must be answered. First: What shall we measure? Second: Why should that measurement be made? And third: How shall we measure it? Too often the second question is ignored, with the result that indirect and complicated measurements are made that have but little effect on the control of the essential sizes that should be maintained. The real science of shop measurement lies in knowing what and why to measure, rather than in knowing how to measure.

The problem of proper shop measurements is closely allied to the problem of proper dimensioning of drawings. A fundamental law of dimensioning is that dimensions should be given between those surfaces which it is essential to hold in a specific relation to each other. If all drawings rigidly adhered to this rule, in most cases the problem of shop measurements would resolve itself into the problem of how to measure the dimensions shown on the drawings. Unfortunately very few drawings comply with this law in all respects. Too often the position of the dimensions on the drawing is governed more by the convenience of the draftsman than by the essential interrelation of the surfaces dimensioned.

To a great many people, the purpose of measuring is to see that the parts as made agree with the drawing. This is not their true function, however. The main purpose of measurement is to prevent unsatisfactory parts from being produced. The testing which may be done later is but a supplementary check on the work accomplished. Measurement, or inspection, to be most effective should be used as a preventive, and not a cure. The time to prevent errors is when the metal is being shaped to size or form, and not after the work has been completed. The object of measuring or inspection after individual machining cuts or entire pieces have been completed is to insure that all parts which will function properly are accepted, and that all parts which will not are rejected as the defect exists, to save the expenditure of further effort on useless parts. When the drawings truly and definitely record the requirements of acceptable parts, they may safely be adhered to. Until then they will either be ignored in part at least, or else unnecessary expense will be incurred in the production of the parts.

When the question, "Why should that measurement be made?" is asked, and the answer is that there is no particular reason why it should be made for any purpose, it is evidence that the dimension in question should not be on the drawing. If the point or surface in question is not dimensioned from any other point, a search should be made for its most essential interrelated surface, and its measurement should be determined from there. If it should already be dimensioned from there also, the first dimension is not only superfluous but also misleading, because if care were not exercised the position of the surface in question might be established from a non-essential register point instead of from the really essential one.

If all measurements were absolute it would make little difference, perhaps, how the various positions were determined. But as they are not absolute, this matter of what measurements are made becomes of vital importance. The probabilities are that if two measurements are made to determine a position where one measurement would answer, double the variation will be present; if three are made, triple the variation, etc. This holds true whether the measurements are made to determine when to stop the removal of metal or to determine the finished size. In the case where the proper functioning of the surfaces in question requires a definite degree of accuracy between certain essential surfaces whose positions are thus indirectly controlled, it results in the necessity of a far higher degree of accuracy—which is always expensive—in

the machining and measuring of several supplementary surfaces than is actually required between the two essential surfaces. This increased degree of accuracy required will be in direct proportion to the number of supplementary measurements made to control the essential dimensions, and the cost of maintaining these supplementary surfaces to the unnecessary degree of accuracy thus demanded will increase far more rapidly.

One fact should always be kept in mind. A high degree of accuracy is very expensive and does not always serve any useful purpose. Any surface should be held to that degree of accuracy truly required, and no closer. Every functional surface of a mechanism has more or less definite limits of size within which it will operate properly. In some cases the extent of the permissible variations is very small; in many other cases it is relatively large. No useful purpose is served in arbitrarily holding all variations to extremely small amounts regardless of the conditions to be met. The object of manufacturing is not to see how closely certain sizes can be held, but rather to produce various commodities as economically as possible.

Where repetitive work is involved, it is customary to make up various types of work-holding devices, such as jigs and fixtures, to facilitate the several machining operations on the component parts of the product. Any errors which exist in the essential parts of these work-holding devices will also be present in the product which is produced from them, in addition to the unavoidable variations which develop in making the machining cuts. Therefore the errors in the functional or locating elements of such equipment should be kept at a minimum. In such cases the expense of a relatively high degree of accuracy is justified because it is incurred but once for the benefit of all future production on this equipment. Furthermore, appreciable inaccuracies in this equipment require a higher degree of accuracy in all operations performed with its aid than would otherwise be required. In work of this class the degree of accuracy sought should be the highest degree that can be reasonably attained.

These same considerations as regards accuracy hold true to a somewhat lesser degree for cutting tools which control the size or form of any finished surface. If the life of such tools were as great as the life of the jigs and fixtures, the expense of the same degree of accuracy would be justified. Usually, however, their life is very much shorter. The economical degree of accuracy required is therefore governed largely by the degree of accuracy required on the product, and the increased expense of a higher degree of accuracy on the part of the cutting tools as compared with the decreased expense of producing parts to the required limits with the more accurate tools. In general, the amount of variation permitted on such perishable tools should be not less than half the total variation permitted on the product.

The whole problem of permissible variations, or tolerances, is a very vital one, involving not only the manufactured product itself, but also the tools and other equipment used to produce it. If the tolerances specified are closer than are actually required, unnecessary expense will be incurred in meeting them; if they are too liberal, an unsatisfactory product will result.

There is a limit to the degree of accuracy which can serve any useful purpose in machine-shop practice. For example, a difference in temperature of several degrees often exists between a part as it is just completed, and still somewhat warm from the heat of the cutting operation, and one which has been completed for some time and has cooled to room temperature. Also a somewhat similar difference in temperature often exists between a measuring instrument which has been held in the hand for some time, and parts which are being picked up and measured successively. This difference will often amount to fifteen or twenty degrees, and sometimes even more. The difference in size due to expansion by heat of this amount will be about one-tenth of a thousandth of an inch per inch of length. It should be obvious that with such variations due to temperature present, the relative sizes of similar parts under these conditions cannot be controlled to the tenth of a thousandth. Whenever the degree of accuracy required is less than one-quarter of a thousandth of an inch per inch of length, suitable precautions as regards the temperature must be taken. Whenever it begins to approach the tenth part of a thousandth of an inch per inch of length or less, the determinations must be made in a controlled-temperature room, and many other precautions must be taken, if dependable results are to be obtained.

Comparative Methods of Tool Design

(*Continued from page 534*)

and the punch above. Another method is to hold the work between two jaw-pieces pivoted from a common point to swing together against a stop pin—the scrap being removed when these jaws are open.

As yet, an automatic die-making machine for blanking dies has not been worked out satisfactorily. However, this may in time be accomplished, similarly to a well-known machine now on the market which automatically engraves intricate designs on dies for coining, embossing, and forming articles of all sizes from the smallest parts to automobile fenders, etc.

In die making, hardening and tempering, as well as the grade of steel used, are vital factors. Quite often an expensive die will be made, only to be ruined in short order by improper hardening. Dies call for the greatest care in hardening and tempering. The grade of steel used will of course depend on the requirements. Often high-speed steel will stand up better than ordinary tool steel, or vice versa. Frequently machine steel, case-hardened, will answer, especially for bending and forming dies. Cast iron may also be used to advantage for forming or drawing dies where the quantity of blanks required is not too great.

In conclusion, it is desired to give Mr. Oberlin Smith due credit for his work in developing die construction for sheet-metal work. It is at this time plain that the production of sheet-metal articles is still in its infancy, and that much can be done to improve manufacturing methods in this very important field in the designing of dies and special machinery.

Standardization Versus Individuality

(*Continued from page 530*)

the result of few wrenches is reached by standardizing the heads of screws and bolts, the flats of nuts, etc., to suit the wrench sizes, even at the sacrifice, in some cases, of following an established formula for the proportions.

Preferred Numbers

In the discussion of standardization, the proposal has been made that a series of preferred numbers be chosen from which selections will be made when standards are to be established. A German system of preferred numbers has been suggested, based on a geometrical progression, although departing to a considerable extent therefrom in order to secure even sizes. An analysis of this system and a comparison with the present German standards affecting machinery and tools shows that even in the metric system it is not well adapted to most of these standards; and such metric standards as gear systems, arbors, tapers, tee-slots, screw threads, and many others would have to be radically changed from those at present in use in order to make them fit the German preferred numbers. It is held to be more essential that sizes covering general proportions of a new standard should be in geometrical progression rather than that they should hold to some series of preferred numbers. In the July issue of Mechanical Engineering, C. C. Stutz, secretary of the American Institute of Weights and Measures, has clearly pointed out certain limitations of the German preferred-number system, and has suggested a basis on which a much more rational system of preferred numbers, suited to American and English practice and based on the inch, could be adopted, although he, too, emphasizes the fact that to secure a geometrical progression is the prime consideration.

Conclusion

The conclusion reached from this discussion is that there is danger of overstandardization if we dive into it headlong without due regard to established practice and to the cost and confusion of changing. It would seem that the more conservative practice of the British Engineering Standards Association might with advantage serve as a guide to us in America, rather than the wholesale standardization which has been in vogue in Germany since the war.

Forecasting Demand for Industrial Equipment

The Business Cycle in the Machine-Tool Industry—Coöperative Study of Stabilization—The Machine-Tool Barometer

By ERNEST F. DuBRUL,[1] CINCINNATI, OHIO

CERTAIN economic forces unfavorably affect all equipment industries and make them more subject to irregular operation than industries making consumer goods. These forces affect the well-being of all participants in these industries, wage earners, salaried staff, and investors. Their operation and effects have not received the consideration they should have had from the thinking or planning staff of those industries—otherwise the unfavorable effects would be less marked than they are.

Every month Dun's Agency reports failures by number and amount of liabilities, classified by the various branches of manufacturing and trading in which the bankrupt concerns engaged. The class listed as "machinery and tools" leads all the other classes of bankrupt manufacturers. I feel that this is a sinister reflection on the mechanical-engineering profession that first developed the principles of scientific management. I believe that machine-building establishments employ more mechanical engineers than other industries employ technically trained men of their peculiar kinds. To me, this horrible record of failures in mechanical industries shows that engineers have deplorably neglected an essential part of their profession. The problems of the balance sheet must be studied by engineers as well as the problems of the drawing board, or of the time-study room.

Economic Studies of the Business Cycle

The wrecks and losses of the post-war slump have done some good by awakening business men to the facts of the business cycle. For some years before 1912, Prof. Wesley C. Mitchell had been collecting and studying statistics of industry and finance, seeking a foundation for a logical, coherent theory of business cycles. He published his material in a monumental book, printed in 1913 by the University of California. The value of the work was soon recognized by students, and the small edition quickly found its way into reference libraries. But very few business men knew of this book, and very few based their business policies on its finding of facts.

It is particularly interesting to those engaged in equipment industries to know that the economists have segregated certain significant facts with respect to those industries. In 1911, George H. Hull, an iron merchant, published a book, Industrial Depressions, in which he traced the cyclical causes and effects on demand and operation in construction and equipment industries. Professor Mitchell's book carried Hull's analysis further. In March, 1917, Prof. J. Maurice Clark published an article in the *Journal of Political Economy* going still further into the analysis of these conditions. Professor Clark pointed out that equipment demand is dual in character, that machines are bought for replacements, and for expansion of facilities to take care of increasing demands for the product of the machines. He showed that these two classes of demand acted differently. Replacement demand varies roughly with the amount of product made, and expansion demand varies with the rate of growth in demand for the product of the machine.

A moment's thought will show that this fact makes management of machine-building shops decidedly more difficult than that of factories using the machines to make consumer goods. Take a machine shop built to supply one user's expansion demand for a time. Before the demand for the final product actually falls off, it begins to slacken in rate of expansion. So the machine user does not order machines as fast as he did before. If his demand stops growing, even though it does not decline, he needs no more machines to take care of growth. The machine builder is entirely cut off from that user's expansion demand, and finds himself with a plant much too large for the economical supply of mere replacements. Until and unless he can find other customers or make other product, the excess plant is a social waste. If the price charged for the machines produced did not recoup the cost of the plant, or cover depreciation and obsolescence until again employed, the user has gotten his machinery below its true cost.

I am convinced that this vital fact accounts for many business failures in the mechanical industries. Such conditions lead to desperate attempts to get enough business to keep heads above water until demand catches up. Then the process is repeated, with the same blindness as before, by those who have managed to survive. Of course all industries are subject to this disease, in some measure, but none are attacked by it as badly, or as often, as the equipment industries of all sorts. Therefore engineering time and thought directed toward alleviation is effort well spent.

Reduction of Industrial Waste

What can engineers do to reduce these great social wastes? The first thing to do is to get the facts bearing on the problem. The most necessary facts are those that relate to the state of these markets. The makers of any commodity, being few in number compared to the users, are naturally the most practical source from which information can be collected.

Suppose that users of various commodities were to have had their trade papers say something like this, in February, 1920:

> The unfilled orders for this commodity at the end of January, 1920, were U per cent of capacity of the plants; users ordered O per cent, which was X per cent in excess of reasonable requirements, indicating that many of these orders will be canceled, and indicating injudicious overselling on the part of the producers. At the same time, the stocks of the commodity were W per cent of the capacity of the plants. The production for February was P per cent of capacity, which is Y per cent more than needed to supply average needs. Shipments were S per cent of capacity, being Z per cent more than enough to supply reasonable average needs. Prices are unduly high because users are ordering more than prudent policy dictates. Unless they stop this mad scramble for actually unnecessary goods, prices will go still higher. Users' stocks are reasonably adequate for all prospective demands. To increase these stocks by additional commitments is the height of folly. Hand-to-mouth buying and selling should be the rule from now on.

Such information and interpretation could have been broadcasted to any market had full statistics been available to competent and unprejudiced observers, and had users and producers both learned sound methods of interpretation. The country could have saved several billions of dollars lost in that spring's booming folly, which finally resulted in the depression losses of 1921.

Coöperative Study of Stabilization

Let me cite the machine-tool industry as an illustration of what can be done in coöperative study of the economic problem of stabilizing employment and production.

For many years the machine-tool industry has suffered to the full from all the conditions imposed by irregularity of demand. Its peaks are high and sharp; its depressions deep and broad. It always has suffered from the futile attempts of ill-informed participants to increase their own volume in a depression, by cutting prices below true costs, and thereby to take business away from competitors who were often in a better financial condition than the price slaughterers. Every depression saw the overstocking of the industry with tools of the preceding boom's vintage. It saw more or less obsolescence of these stocks and newer designs brought out to get ahead of competition. It saw the newer, better, more costly designs sold at smaller and smaller margins of profit.

This cycle of recurrent events led the industry to desire to study its economic conditions and to identify the causes of its frequent distress in the hope of working out remedies if possible. This program was decided upon late in 1920, when the post-war depres-

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Contributed by the Machine-Shop Division for presentation at the Machine-Tool Meeting, New Haven, Conn., Sept. 15–18, 1924. Slightly abridged.

sion was well under way, and the program was started with the beginning of the year 1921. It was desired to get some idea of how the demand had actually acted. The most readily gathered statistics were those of the number of machines shipped, so, early in 1921 these data were secured from 29 representative companies covering their annual shipments for the 20 years 1901 to 1920, inclusive. The figures were carried on for the three subsequent years.

Conforming to the practice of the Department of Commerce, these figures were reduced to an index number, taking 1913 as the base year. The result is shown in Fig. 1. On the same chart is drawn a trend line, or line of normal growth, based on the fourteen years before the world war. This line showed a normal growth of about 2.3 per cent per year, compared to the 1913 base.

It was desired to compare the industry with another to which

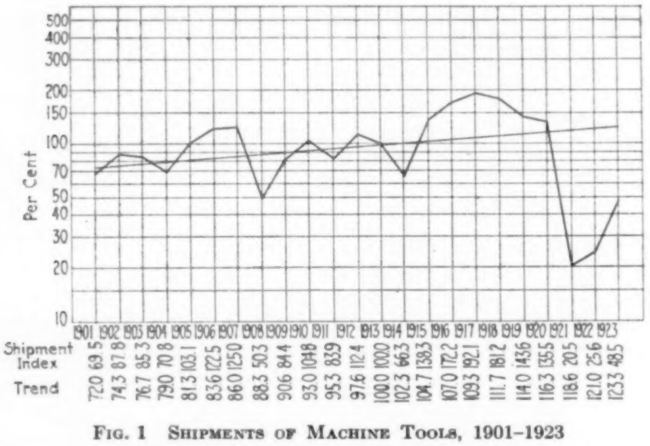

Fig. 1 Shipments of Machine Tools, 1901–1923
(From reports of 29 firms. 1913 = 100 per cent.)

Fig. 2 Percentage Deviation from Trend, Pig-Iron Production and Machine-Tool Shipments
(Trend based on years 1901 to 1914, incl.)

it was economically allied, and whose feast-and-famine conditions were traditional. The percentage deviation from the trend for fourteen years was applied to pig-iron production and machine tools, with the results shown in Fig. 2. This shows that these machine-tool builders had greater irregularity in every cycle. These facts confirm the conclusion of Professor Mitchell[1] that under our present economic system the machine-tool industry's problems lie more in the economic field than in the technical fields of design or production, important as these fields necessarily are. Professor Clark[2] has said:

> Making all due allowance for mitigating factors, it is difficult to see how the machine-making industries can possibly avoid the disagreeable experience of outgrowing themselves in times of prosperity. For demand can never be expected to grow at an absolutely steady rate, and the slightest fluctuation seems destined to put the producer of capital goods in a situation like that of a passenger forcibly carried by his station.

[1] Business Hazard in Machine-Tool Industry, W. C. Mitchell, *American Machinist*, Jan. 3, 1924.

[2] Economics of Overhead Costs, J. M. Clark, 1922, p. 390.

The thoughtful machine builder must conclude that as he cannot greatly change the nature of his demand, he must learn to adjust his business policies so that he will not be ruined by its fickleness. He must see that neglect of that adjustment can easily put him individually out of the running, and at the same time undermine the financial strength of the whole industry.

To know what adjustments are needed, we must keep track of changes in the industry's current demand. With the variety of its product, this presents some difficulties because there is no common unit of measurement, except dollars, to measure demand for small sensitive drills and large planers or boring mills. Another difficulty lies in the fact that the industry is as individualistic in its ideas of management as it is in its designs. It was not possible to get many companies to coöperate in giving dollar figures. Some day, with growing knowledge of their value, it is hoped than these, too, will be available. They would be of more benefit than the present method.

Our only recourse was to fall back on some sort of index. Members were asked to report their own current monthly orders and cancellations, as a percentage of their average monthly value of orders received during the first quarter of 1920. These percentages were then averaged and reported back as a monthly index. This is

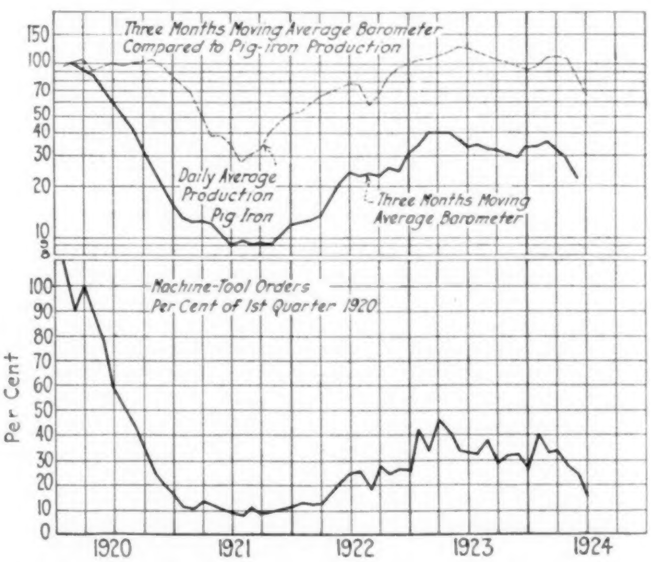

Fig. 3 Barometer of Machine-Tool Orders, Per Cent of First Quarter of 1920

far from the best index that could be devised as a pressure gage for the industry, but it is far better than nothing at all. The course of this so-called barometer curve since January, 1920, is shown in Fig 3, giving the three months' moving average to smooth out the curve.

For two years we checked this with the quantity statistics of orders received from the twenty-nine members reporting numbers of machines. The two series show some variance, but in general the correlation is close enough to show that the method of averaging percentages is reasonably serviceable in showing the trend of demand.

Relation of Machine-Tool to Other Business Indexes

Our next problem was to tie up this barometer curve with other business indexes, so as to study the relative actions between them. Search had to be made among available statistical series to discover which of those currently reported preceded the rise and fall of machine-tool orders from 1920 on. We also had to find if such precedence was in accord with the theories of the cycle formulated by Professor Mitchell and others.

We have discovered an easy method of comparing curves of various kinds that lead or follow others, and to untangle many a puzzling condition in the warp and woof of industry's pattern. Some curves of small amplitude of fluctuation are seen to be relatively quite as sensitive as those of very great fluctuation when plotted together in the same field.

Here I am glad to acknowledge the valuable assistance rendered in this research work by Mrs. Frida Selbert of the National Machine Tool Builders' Association office staff. On her has fallen the tedious work of computing and checking data and plotting our various charts. I am indebted to her for many constructive observations on the correlation and significance of various factors studied in this way.

Fig. 4 shows the three most significant series of data we have so far found to precede our machine-tool barometer. These are (1) Commercial 60–90-day paper rates (inverted to serve as an index of supply of business funds); (2) The Standard Statistics Company's index of 202 industrial stocks quoted on the New York Stock Exchange. This serves as a good guide to speculation; (3) Orders for clay firebrick reported by the Refractories Manufacturers' Association. This has been found to be a more sensitive index of business activity than machine-tool orders. Fig. 4 shows all these curves plotted on the same scale, and gives an idea of how widely they differ in fluctuation. Fig. 5 shows all these curves, plotted so as to throw the present cycle into the same field from the low points in 1921 to the high points in 1922 and 1923.

Besides the three months' moving averages of the various series, we use twelve months' moving averages plotted in the same field to furnish us confirmations of our conclusions. A curve of twelve months' moving averages gives a very satisfactory trend picture of any statistical factor.

Use of the Machine-Tool Index

The next question is, "What practical use can buyers and builders of machine tools make of information like this?" First consider its value to the builder. He now has a demonstration that his demand picks up several months after many other indexes pick up. Therefore he need not fear that he will not have ample time to accumulate a reasonable stock on his shelves and floors, so as to be able to supply his trade when his customers want machines that can be made wholly or partly to stock. More than that, he now knows that prices of materials lag behind these indexes. Therefore he can be sure that by watching his material market he can accumulate supplies to much better advantage after his own industry's orders start up from bottom. Formerly he was accustomed to accumulate supplies just at the highest cost, and to carry them for a long time.

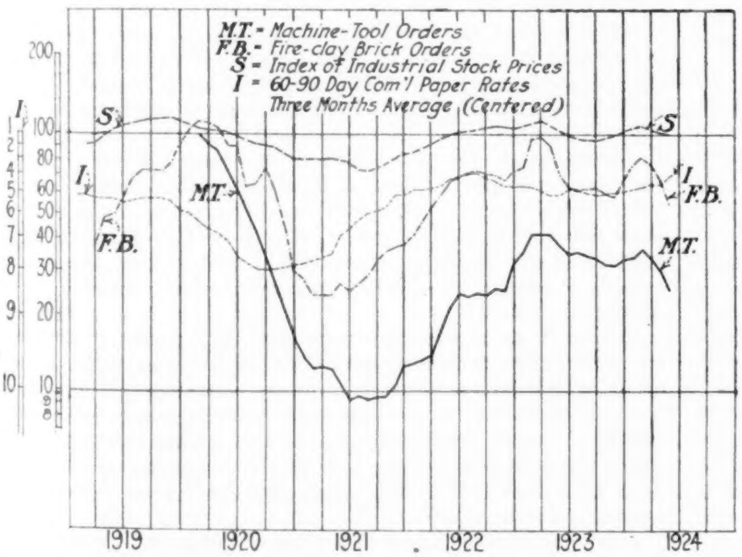

FIG. 4 RELATION OF MACHINE-TOOL TO OTHER BUSINESS INDEXES

It is decidedly valuable for the machine-tool builder to have two or three good indexes warning him of a coming recession in his own demand. By keeping his eye on them he need not be tempted to keep a force of inefficients at work, as has been the case at every peak. He will have much clearer vision when he comes to answer the question, "Is it better to lay off such men and conserve cash, or should I keep them on and make to stock?"

If he lays out his sales policies so as to get in a fair sprinkling of special work and besides offers machines that can be made to stock, he can keep a more flexible organization. Production and shipments of made-to-order machines will lag the actual receipt of orders by some time. As such orders are filled on a recession, key men can be swung into repairing equipment or to making jigs to make the new types that should be designed ahead, ready for the next rise.

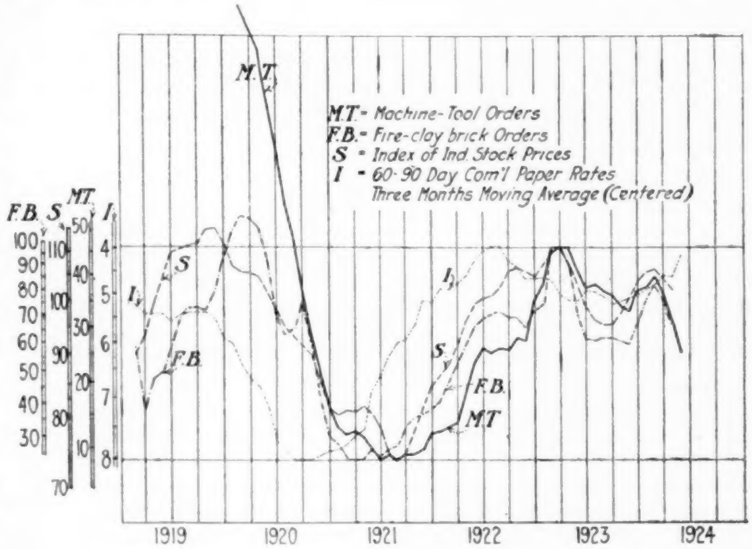

FIG. 5 REPLOTTING OF FIG. 4 TO BRING INTO THE SAME FIELD CYCLE FROM LOW POINTS IN 1921 TO HIGH POINTS IN 1922 AND 1923

After the rise has started, stocking of parts can commence with those requiring the most labor and least material, until material prices show signs of bottoming. Then the heavy stock parts should be driven ahead. In this way the best use of cash resources will be had, and obsolescence of stock will be minimized. Construction and expansion programs can also be arranged to greater advantage.

By controlling his design policy so that new designs come out during depressions he will give his salesmen something new to talk about, just when his customers have the most time to listen. In the past, just when his customers had many old-style tools standing idle, he was generally wasting money sending salesmen to try to sell them more of the same old styles. Then when he did get out his new designs his customers were too busy producing goods to study new methods.

In dull times most users lack either will to buy, or power to buy, or both. But in such times all of them have time to listen if the salesman has something new to tell them, so that is the best time for missionary work in advance of sales. Even in dull times some users have power to buy, and can be induced to exert will to buy if shown a new cost-reducing machine tool. They can be made to covet a tool that will give them a jump on their competitor, and at the same time put their funds to producing bigger returns than are to be gained by investing in some other industry's securities. The chances of getting orders are improved by this sales policy. Doing missionary work on new designs in dull times proves to be better utilization of sales effort and expense than trying to sell old-style machines of which users have plenty.

On the buyer's side, data of this sort show how much idle time the buyer has to pay for because he bunches his orders at the wrong time. Of course the great mass of buyers will continue in this wasteful way. But the more thoughtful ones will know that it is to their advantage to buy when direct costs of labor and material are the lowest. The machines bought in dull times will be produced by the picked men that the machine builder is most anxious to keep at work. The work will not be hurried and there-

fore it will be better done than when the builder is rushed to distraction. Deliveries will be easier to get at the time wanted, and the buyer will have a better chance to install up-to-date machines without interfering with his own production.

By making his purchase in advance of his needs, the user gets other advantages. He is able to ship a lower-cost product just when his improvident competitor is frantically combing the market for machinery, and taking anything that he can lay hands on. Some dilatory buyers nearly always pay more for poor machines than their wiser competitor paid for good machines bought a few months before.

Then the broader social aspect must not be overlooked. Besides the direct benefits to be gained by users and producers of equipment, there is a social benefit accruing to all humanity. As the equipment industries learn to save the wastes of idleness, some of the funds so salvaged will be spent in development of newer and better machinery. The equipment industries will thereby further increase the productivity of man power, and further increase the physical amount of consumer goods of all sorts made available to wider consumer markets through lower costs.

We can get more coöperation of the sort needed by having engineering brains as well as business brains working on this problem of cutting off the peaks and filling up the valleys of the cycle whereever possible. As time goes on, more and more equipment buyers will use various economic indexes to guide their policies in expansion and replacement. When many large buyers do this, we shall see less irregularity in demand and operation of all equipment industries in which so many mechanical engineers are engaged. The effort to bring about such stabilization seems well worth the active support of every mechanical engineer.

Aerial Bombing

Further Information on This Important Subject, Dealing with Damaging Distances for Various Sizes of Bombs, Yawing and Sight Stabilization, Tactical Requirements for Service Bomb Sights, Etc.

IN A PAPER presented at the Spring Meeting of the A.S.M.E., Cleveland, May 26 to 29, and published in the June issue of Mechanical Engineering, page 309, Major A. H. Hobley[1] and H. B. Inglis[2] dealt with the subject of aerial bombing, discussing, among other things, early practices and conditions, the bombing of moving targets, the theory of bomb trajectory, principles of various sights, ground-speed determination, and sources of error and methods of overcoming them. A brief account of the discussion of the paper was published on page 412 of Mechanical Engineering for July, in which it was stated that a communication from Dr. E. J. Loring[1] dealing with technical points involved in bomb sighting would appear in a later issue. This communication, together with the authors' closure to the discussion, is printed below.

G. S. Curtis. Referring to errors due to under oscillations, the relative drift appears to change in direction and of course in amount, but no accurate method seems to be indicated in the paper for averaging this amount in order to correct for actual drift. If a stabilized sight is used, does it stabilize yaw and intentional change in direction?

E. J. Loring.[3] Prior to the spectacular tests on the German ships, the damage which might be inflicted with penetration in actual dropping operations was entirely unknown. In fact, there were several opinions as to the proper point of attack, one being to penetrate the deck, for which purpose an armor-piercing bomb was produced; another view was that the most favorable point for damage was close alongside. There was also very grave doubt as to what size of bomb would be necessary: the 1100-lb. was the largest then available, and for a decision on this point a 2000-lb. bomb and later a 4000-lb. bomb were produced, although the latter was not used. The question of accuracy was entirely secondary. The first consideration was the effects on the ships.

In the case of the operations against the *New Jersey* and *Virginia* last fall, the first flight of Martins with 600-lb. bombs at 10,500 to 11,500 ft. was much more of an accuracy test. In the attack on the *Virginia*, no one who saw the effect of the fifth bomb dropped would expect to find any anti-aircraft guns remaining in operation. This hit penetrated the light rear deck and swept it forward nearly the length of the ship over the forward turret. It may be contended that damage such as this may be made less likely by heavier decks, but weight can scarcely be added over the entire deck of the ship without a reduction of weight elsewhere. This bomb demonstrated the new danger from decks which may be penetrated, even if not over vulnerable parts of the ship.

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[2] In charge of Bomb Sight Division, Engineering Division, Army Air Service, Dayton, Ohio.
[3] Ordnance Engineer, Army Ordnance, Washington, D. C. Mem. A.S.M.E.

Damaging Distances for Various Sizes of Bombs

The damaging distances for various charges were not determined, the observers having been too far away in all these tests to note accurately the distance of the bombs from the side of the ship. The best available data[1] indicate that our 300-lb. bomb will give a damaging pressure at 18 ft., if over 6 ft. deep below the surface; the 600-lb. bomb at 27 ft., if over 12 ft. deep; the 1100-lb. bomb at 36 ft., with 22 ft. depth; and the 2000-lb. bomb at 45 ft. with 30 ft. depth.

The paper gives an excellent answer to the statement that anti-aircraft fire and high-speed pursuit planes will bring down the bombing plane or turn it from its target. The speed of the airplane is its best defense against attack from the ground, though speed alone is not sufficient defense against attack from the air. But the bomber is not defenseless against attacks from the air. It can mount several guns, which can be pointed in any direction and may be of good caliber, up to 37 mm. The bomber has no "blind spot" and is not obliged to shape its course in order to place its gun shots. Moreover, it will seldom have to fight single-handed; bombing planes will be in squadron formation, capable of massing enough fire on any attacking plane to make short work of it.

It must be admitted that every effort is being made to improve anti-aircraft fire, both in range and direction. From the results of firings against targets towed by airplanes, aircraft people may find, however, that there is a most favorable altitude, somewhat dependent on the speed, above which the distance is a handicap and below which the motion is too rapid to permit a satisfactory reaction. Thus an anti-aircraft battery might find itself nearly defenseless against a diving attack.

There has been confusion in the use of the term "terminal velocity," or that at which the resistance of the bomb in air of standard density is assumed equal to the weight of the bomb, resistance being assumed to vary as the square of the velocity. This is never realized with an actual bomb, in part because the velocities seldom run so high in actual bombing operations, and also because the resistance of air at velocities near that of sound is materially higher than here assumed.

The statement that variation of trail angle with altitude has hitherto been ignored is not correct. While this work was in the Ordnance Department during the war all bombsight computations were based on trail, with all variables considered, and not on trail angle.

It may be noted that with a given wind and constant air speed the point O_3 of Fig. 1 [Fig. 3 of the original paper] is common to

[1] Based on General Abbot's experiments with assumption of the strength factor for TNT.

flight in all directions on to the target O_2. Also, that in the relative motion between the plane and the ground in the case where there is wind, the apparent effect of the wind is to blow ground objects away up-wind. Thus in Fig. 1, the wind has not changed the relation of the bomb and the plane, but only their relation with the ground. If the point O is taken as a center and a circle described with radius OV, this circle will be the locus of the points of release for the target O_2; the plane will be pointed toward O, and drifting over O_3.

Two typographical errors are noted in the discussion of errors; the type of bomb selected is of 1000 ft. per sec. terminal velocity, and not 100 ft. per sec. Also, under errors of alignment, 44 ft. is of course subtended by 5 deg. from 500 ft. altitude instead of 5000 ft.

The manner of installing the pitot head of the air-speed indicator

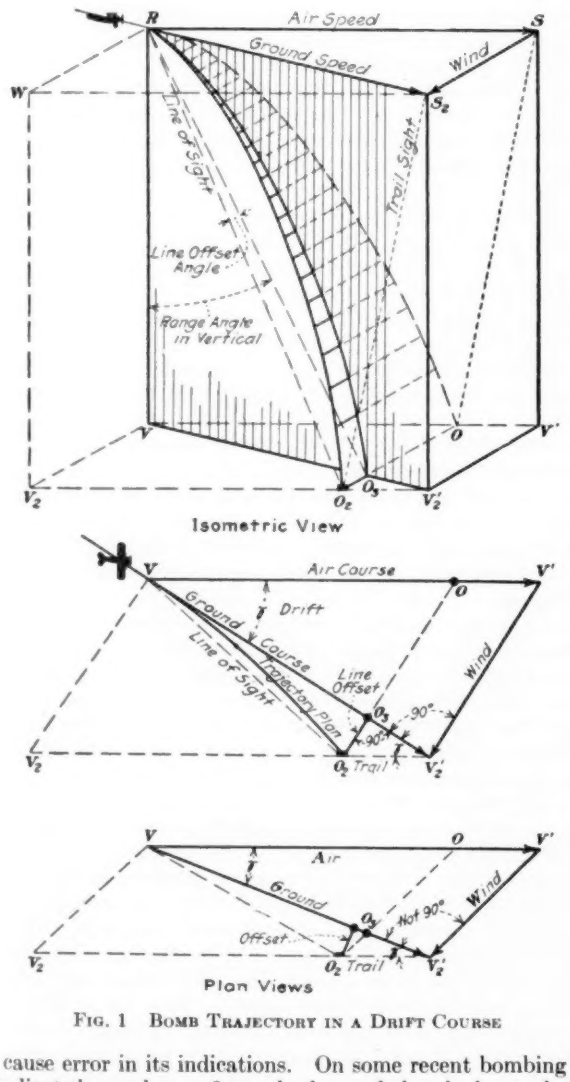

Fig. 1 Bomb Trajectory in a Drift Course

may cause error in its indications. On some recent bombing tests the indicated speed rose 2 m.p.h. for each bomb dropped, while the surveyed speed remained the same. There may also be an error in the use of a venturi-pitot head since the results with variation of density or altitude with heads of this class do not follow a single fixed law, whereas in a pitot head the indications are proportional to the square root of the air density and the bomb sights are calibrated on this basis to make use of the indicated speed without reduction to the actual speed.

Errors of level of the flight path are often over 2 deg. Pitching errors are not limited to errors of observation; a bomb released during a pitch receives an initial transverse rotation that affects its flight. The effect of the fins or stabilizing surfaces of the bomb enters into the action, and as a stable bomb released without rotation will tend to fly with the nose lagging upward, we find a general tendency to travel beyond the theoretical distance, so that occasionally one travels ahead of the plane, while there have been apparently authentic cases where bombs with short range have reached the ground in less than the time for fall in vacuum. A horizontal curvature in the path of flight amounting to over one-third of a degree per second is also not infrequent.

The chief difficulty of the synchronous method of operation appears to be that the operator is never certain that he has obtained synchronism, and is always touching up his adjustment so that the final touch is quite likely to give a very erroneous adjustment. It appears to the writer that this method becomes practical only when so arranged that the operation of resetting to synchronism on the target also corrects the adjustment of rate to distribute the error over the preceding five to eight seconds. Apparently synchronism can never be determined except by an accumulation of error. A sort of reversed synchronism has a certain merit; in this idea instead of making an attempt to stabilize the apparatus and synchronize a line of sight on to a target the operation is reversed, the line of sight is held on the target and the developed error of level or departure from a stabilized indicator is observed.

Another type of sight has been developed on a somewhat different principle. The sight is stabilized and settings are made by a timing operation on a preliminary portion of the flight. The settings being completed, the sight then indicates continually the point on the ground that would be hit by a bomb released at the instant of observation, there being automatic means for correcting for all changes in the relative direction of the wind. The plane may then be handled as a gun, until the line of sight intersects the target, and the path of straight flight may be exceedingly short.

Successful bombing is dependent on careful procedure and continued practice of the bomber and pilot together as a team. It can be shown from the bombing of the German ships that the accuracy of each team improved with each flight. In the final shot on the *New Jersey* last fall, the bomber, Sergeant Nero, withheld release until he had his position just where he wanted it, making four flights over the ship, and his bomb went clear through the ship, sending it down in about six minutes.

Tactical Requirements of a Bomb Sight

A statement of bomb-sight requirements as prepared by the Ordnance Department a few years ago is as follows:

The tactical requirements of a bomb sight are:

1 That it may be sighted on a preliminary target and then permit a change in direction in approach to the target itself.

2 That it may sight on the target itself without the use of a preliminary target.

3 Must be simple enough to be operated by an ordinary observer without interfering with his functions as a gunner.

4 The sight must be stabilized so that the oscillation of the air lane will not influence it.

5 It must enable the bomber to bomb at any angle with the wind.

6 The sighting interval must be as short as possible.

7 The elimination of a supplementary aiming point is desirable.

8 An adjustment to enable bombing at a moving target would be a desirable feature.

9 It must permit bombing at any altitude up to 20,000 ft., day or night.

10 It must be so designed that it can be conveniently located in the airplane in a position protected from the wind.

11 The usual adjustments for altitude, air speed, ground speed, and lag angle must be possible, also adjustments for different types of planes.

The authors may have in mind other requirements, and it would be very desirable if a complete and up-to-date statement of this kind could be made.

The Authors. Dealing first with Mr. Curtis' question, the line of sight to the objective lying in the same vertical plane with the longitudinal, horizontal direction line or wire, must be effectively stabilized against rolling of the airplane.

While the pilot is holding a steady approach, rolling, pitching, and yawing oscillations are momentary and of small degree; the bomber holds his line of sight in the center of such apparent momentary movements of the target. This reading of the average of the oscillating pointer is almost as accurate as though a pointer were strictly "dead beat." For the conditions in flight, steadier

direction is thus obtained than by the bombers attempting to give the pilot indication for every momentary oscillation, which would only increase the amplitude of the pilot's direction pointer, or for the pilot to attempt to control the airplane for each momentary oscillation, with the invariable result of overcontrolling. Again, alignment of the airplane's ground course over the target does not actually deviate by nearly the extent of such momentary oscillations, but is maintained within a fraction of a degree because of the heavy bomber's inertia.

Yawing and Sight Stabilization

Sights have not been stabilized against yawing for two reasons: first, because the apparent motion is averaged visually, while yawing does not change the actual ground course to any appreciable extent; secondly, the bomber must sight and correct the alignment constantly so that he is correcting any yawing which is sufficient to change the course appreciably.

While the sight itself might be gyroscopically stabilized against yawing on a vertical axis, or upon the objective once aligned, it will be seen that inasmuch as such a yaw as involves change of actual ground course also necessitates correction of alignment and change of the stabilized reference, any stabilized pilot director such as a turn indicator or earth inductor compass already performs the function; also that the bomber's manual holding of an optical line of sight upon the objective makes the only correction necessary, that is, for change of the ground course.

The throwing off, by yawing, of a pendulous sight which may be mounted off the vertical axis of yaw, would of course not be prevented by stabilizing the sight in the ground direction, so that the only advantage would be to reduce the visual oscillation of the objective which, as stated, does not offer any serious difficulty or error in holding the average; and when the sight is manually held, there is no appreciable movement at all.

For intentional change of direction, as in correcting alignment, the stabilizer is oriented with the sight, in the target direction, so that the sight is stabilized for any component rolling or pitching with respect to the ground course, which extreme yawing may produce.

It may be of interest to add, that the highest precision in alignment has been obtained by utilizing the principle that if the ground course is *not* toward the target, then a line of sight held on the target has a lateral movement with respect to the fuselage as approach continues. This angular motion of a line of sight merely held upon the objective by the bomber is made to offset a pilot pointer in a magnified degree, and the pilot turns until he has zero reading, when there is no lateral movement of the bomber's sight. By this device the ground course is quickly and most accurately aligned upon the objective from any direction, in any unknown drift, without any knowledge of wind speed, air speed, or ground speed or their directions, and without the necessity of observing the ground drift at all. The accuracy of this method is of course largely dependent upon effective stabilization of the pilot's direction indication against rolling of the airplane which, through corresponding lateral movement of the bomber's sight, would otherwise give an erroneous indication of change of course. The stabilizer is automatically oriented with the line of sight, so that whether the airplane pitches, rolls, or yaws, the component of any oscillation as a rolling upon the horizontal, longitudinal axis of the actual ground course, is completely eliminated from the pilot's indication.

As Dr. Loring has pointed out, the primary object of the joint Army and Navy bombing tests on scrapped battleships was to show the power of destruction of different types of bombs. To those concerned with the use of bomb sights, however, these tests had much interest as a measure of the accuracy of the sights used. The percentage of effective hits was about the same as obtained during the latter part of the war against much larger objectives. The excellent teamwork practice preceding the tests must be credited for obtaining such results with a type of sight that during the war gave a very much worse average.

Increased Accuracy with New Sight Models

It may be of interest to know that whereas about 20 per cent of effective hits thus attained represents the best that can be expected with wartime sights, recent results with one of the newer models (but not new or in first-class condition), accomplished 40 per cent of hits. The actual target was the shadow upon the water of a dirigible, and the results left no question that the movement of a target no longer constitutes any protection from effective bombing. Also the accuracy is such as to enable the bombers to operate from altitudes at which they are usually invisible.

In the pursuit of this peculiar objective, the shadow was traveling at various speeds up to 60 m.p.h. (dirigible air speed plus or minus wind, both being unknown at the time of bombing); the dirigible frequently executed turns greatly exceeding the maneuverability of a battleship; the shadow presented a very indistinctly defined objective and, due to the hazy weather, frequently dissolved out of sight; even when the longitudinal axis of the shadow was distinguishable, the true direction of motion of this target was, unlike that of any seacraft, never known during bombing within 40 deg., not only because of the dirigible's variable drift, across a wind which was frequently not much less than its own air speed, but due to the superimposing upon the dirigible's resultant ground course, of a bodily displacement of the shadow, as the dirigible rose and fell in wind currents. For lack of anything upon the surface of the water to compare the shadow with, the target also appeared to be perfectly stationary and without any wake so that the bomber had no clue whatever as to the direction in which the target was moving.

No attempt has been made to correct for errors due to deviations of the trajectory caused by deviations from level flight at bomb release. Such errors are of an indeterminate nature but have averaged altogether less than the dispersion of bombs of the same type, due to fin deformities, out-of-balance, and slight manufacturing differences, an error which is so small as to give 100 per cent effective hits on very small objectives, if the sight itself is accurate for the normal trajectory, and for assumed horizontal flight.

Wartime sights did not ignore the variation of trail angle with altitude, but its correction for limits of altitude was only approximate. Several sights did provide trail-angle or range-angle corrections by adjustments for various air speeds, but none of them provided sufficiently accurate corrections of the range angle for all combinations of altitude, air speed, and bomb type within the limits encountered.

The hits in the bombing maneuvers in the fall of 1923 were indeed excellent examples of practiced care in getting the results desired, but the repetition of flights over the target sometimes used to correct the sight setting is quite out of the question under war conditions. Thus the modern sight must be set quickly and accurately for whatever conditions are unexpectedly met, without reliance on practiced teamwork and skill on the bomber's part.

The requirements for a successful bomb sight which Dr. Loring wrote some years ago are still essentially correct, and all of them are included in the following Air Service requirements which now have been or can be met. The general problem in the design of a service bomb sight lies in a satisfactory compromise between simplicity of operation and instrumental accuracy. These are of equal importance and are generally conflicting. The development of either one to its extreme has no practical use unless the other is present to a satisfactory degree. Thus the addition of one extra scale setting may more than offset the increased instrumental accuracy which it provides, in so far as it adds any confusion to the operator. Conversely, a sight whose simplicity of operation sacrifices reasonable accuracy has a very restricted field of use—as for extremely low altitudes only, or under assumed favorable conditions—and will be incapable of effective averages with the best of teamwork.

A bomb sight will be finally judged by its results in wartime flight, but the merits of the design can be pretty well judged beforehand, according as it may be adapted to meet the requirements 1, 3 and 4 and, provided it has a probable average instrumental accuracy within one degree error. The authors suggest this empirical basis of evaluation: First, figure the purely instrumental error which the method inherently involves in the setting of the range angle, when all the variables are set in as the method provides, and use the average error for extreme combinations of variables within the limits; secondly, introduce the personal errors involved in its use, arbitrarily assign a $^1/_5$-sec. error for each operation involving

personal time lag of action, 1/32-in. error of observation for every scale reading and setting involved; add all personal and instrumental errors which could theoretically accumulate, then—since they do not thus accumulate—multiply this maximum by the factor 0.3 which has been found to apply empirically to such a comparison of the maximum accumulated error with the actual average results for two wartime sights in general use. Such an analysis would serve at least to eliminate impractical schemes.

Requirements for a Service Bomb Sight

The requirements for a service bomb sight, listed in the order of their importance, are as follows:

1 *Simplicity of Manipulation.* This may be said to be inversely proportional to the number of separate mental and manual operations, including each itemized observation and scale setting and timed action.

2 *Instrumental Accuracy.* By this is meant the inherent error in the range-angle setting, for any given set of conditions, assuming every adjustment to be exactly made as the instrument provides. Instrumental accuracy of alignment is not easily stated. There are various methods which are all theoretically correct but give widely different results, e.g., the Wimperis principle of setting the vector triangle of wind, airplane, and ground-travel directions and speeds is theoretically exact, but premium on time and handicaps against the maneuvering involved do not allow anything like accurate alignment, nor accurate determination of the ground speed and hence the range angle. A very much more practical method is the observation of the ground-travel direction, with the pilot's signal operated by deviation from that reference line of the line of sight to the target. This also establishes coincidence theoretically, yet the results depend to a large extent upon the bomber's careful observation. Actuation of the pilot director by the lateral angular motion of the line of sight to the target involves no observation of drift and is the most accurate in results, requiring but one personal observation. Instrumental accuracy depends upon the degree of correction provided for the following variables:

Variables Affecting Range-Angle Determination

		Error	Limits
a Ground Speed or Relative Speed of Approach Enemy Speed	Determined by the instrument, and automatically entered in range-angle setting	Not to exceed 1/4 deg. in range-angle setting	100–250 f.p.s. 50–300 f.p.s. 0–50 f.p.s.
b Altitude	Read altimeter, subtract target altitude	1/4 deg. in range angle	2,000 to 30,000 ft.
c Terminal Velocity	Set according to bomb type	1/4 deg. in range angle	500–1800 f.p.s.
d Air Speed	Read air-speed indicator	1/4 deg. in range angle	65–130 m.p.h.
e Range Correction for Trail at Drift Angle from Ground Course	Function of drift angle automatically introduced	1/4 deg. in range angle	0–45 deg. drift

Additional Variables Affecting Alignment

		Error	Limits
f Drift Angle	Align resultant ground course	1/4 deg. in final alignment	0 to 45 deg. drift
g Target Speed Target Direction	Unknown but automatically corrected for	1/4 deg. in final alignment	0 to 50 f.p.s. 0 to 360 deg. relative to approach
h Line Correction for Trajectory Offset from Ground Course	Function of drift angle automatically introduced	1/4 deg. in final alignment	0 to 45 deg. drift

3 *Service Operating Utility* (determines probable actual results according as the instrumental accuracy can be used to best advantage).

a Stabilization of pilot's line indication, and of range angle with respect to vertical, to eliminate effects of rolling, pitching, and yawing of the airplane.

b Comprises Requirement 1, as a measure of reducing chances for personal errors of operation.

c Wide field of vision (comprising oscillations within optical field, and free vision at least 60 deg. ahead of vertical and 45 deg. to either side).

d Small overall dimensions and small weight; ruggedness in order to withstand rough handling; adaptable for supporting on floor in lap position; comfortably manipulated in restricted cockpit.

4 *Tactical Advantage* (a measure of probable success under unfavorable conditions).

a Comprises Requirements 1 and 3.

b Small time required to align approach; ability to correct alignment quickly for changes of airplane speed, wind speed and direction, moving target speed and direction; brief time requiring straight flight before release, to set range angle.

c Ability to bomb in any direction, cross wind.

d Ability to bomb moving objectives, from any approach.

e Choice of setting the sight, using the objective only, or using previous object in line of approach.

f Automatic guidance of pilot by indication stabilized with reference to once established alignment.

g Setting of the sight, by automatic continuance of the sight movement function, any time after ground-speed determination, optional with operator's continuance of manual following, by observation of target until release.

h Bomb-sight actuation of bomb release, independent of operator's observation of target intersection at range angle.

Items *f*, *g*, and *h* allow the sight operator to man the guns, if necessary, without waiting for bomb release, the instrument completing its own setting of the range angle once the ground speed has been entered, holding the pilot on the line established, and automatically releasing the bombs at the right instant.

i To align an invisible night objective by sighting upon object of known relation to it.

j To enable correction of the range-angle setting or alignment, for change of any variable, during approach and up to within a few seconds of release.

Discussion of Paper on Pulverized Fuel

(*Continued from page 522*)

referred to was to keep the temperature of the walls below the fusion temperature of the ash. Our experience indicates that unless this is done there will be slagging of the ash, if the CO_2 is kept up to a point necessary for high efficiency.

Theo. Maynz said that variation in quality of coal was not as important with pulverized-coal as with stoker firing. It was easier, he said, to keep much closer to test efficiency with pulverized fuel than with stokers, especially as the coal varied.

R. D. DeWolf. In regard to the point raised by Mr. Van Brunt on the slag, our experience has been that where we have been getting temperatures high enough to melt the ash, the slag builds up to certain thickness on the side walls and then stops. It stays about that same thickness, and unless contraction and expansion take place, resulting in an actual mechanical breakage of the side walls, they seem to stand up in good shape. The flame must be kept away from the side wall, however, otherwise the licking of the gases will cause erosion of the side due to the high velocity and high temperature. From our experience, the problem of keeping side walls in service seems to be largely one of taking care of that contraction and expansion, and letting the slag build up a certain point where wear takes place on the slag itself, which is automatically self-renewing.

G. Keith. We started with flue gases about 250 deg. fahr. entering the driers, lowering the temperature by admitting air into the flue. Gradually the temperature was increased to 425 deg. fahr. We find that if we keep the coal moving we have no trouble from fires. The figures I gave on the capacity of the mill, were obtained with the flue gas entering the driers at 425 deg. fahr. and leaving at 200 deg. The temperature of the coal going to the mill was as high as 300 deg. There were hot streaks in the coal, but the average was about 200 deg.

Measurement of the Quality of Product

By G. S. Radford,[1] New York, N. Y.

The author considers the possibility of reducing control of quality and the inspection function to a mathematical basis, and concludes that this is neither feasible nor desirable. He then sets up standards by which the performance of the inspection division can be judged.

Professor Roe in his paper on the Measurement of Management[2] suggests that quality of output, as an element of production management, be measured by the rating ratio

$$\frac{\text{Goods produced which pass all inspections}}{\text{Total goods produced}}$$

He indicates that "all inspections" should include both the producer's and the customer's inspection. In order to simplify matters, let us first restrict the term to include only the producer's final factory inspection. This paper deals with management in the abstract as applied to all sorts of industries; and as data from the customer's inspection are often lacking, unsystematized, or inexact technically, their inclusion would merely serve to introduce an additional variable without greatly affecting the principles involved.

When expressed in the form of a percentage, the above ratio will be recognized at once as the percentage of goods produced perfect, or in the briefer terminology of the factory, as the "percentage perfect" or "percentage of perfects." Often, from a similar but opposite point of view, the expressions used are "percentage of rejected work," "percentage spoiled," etc.

Very naturally, in view of the fundamental importance of quality, there are no control figures coming to the management's attention which are of greater interest or significance to the future welfare of the business. At first glance, therefore, it doubtless is easy to conclude that the ratio in question is a proper measure of the quality attainment of a given management. Closer scrutiny will show that however appealing this ratio may be from a purely theoretical standpoint, its practical application as a measure of management would yield misleading results in the majority of cases. Stated differently, if the ratio is to be truly significant of the actual situation, then the figures used in its computation must be obtained under conditions which are not reasonably likely to be found in practice.

Where do the figures for this ratio come from? Quantity is fairly easy to measure accurately, wherein it differs markedly from quality; so that the denominator is the total number of articles, pieces, barrels, yards, tons, or other quantity measures produced in the given period of time, or more exactly, the total number presented for inspection.

But the figure to be used as the numerator is quite a different matter. If it is to be a measure of the quality attainment of the management it should be the number of articles which are truly in accordance with certain definite, exact, unchanging, and accepted standards of quality. In practice, however, it is much more likely to be the number of articles which the factory inspection service *considers* commercially salable. Presumably this is what has happened—all the goods in question have been presented for inspection, one or more designated and more or less competent inspectors have compared these goods with the quality standards in use (about which more will be said later), and then have recorded the number which *in their opinion* are in accordance with the said standards.

This would seem to be an appropriate place to observe that the standards in use in the factory are probably set by the management we are attempting to measure, and that the product is graded by an inspection almost certainly dominated by the management. Now if the standards are low or if the inspection is slack, an inefficient management will have provided us with figures for giving it a fictitiously high rating.

If it be argued that quality standards and efficiency of inspection will not change enough in the same plant to exclude the use of the proposed ratio for making progressive measurements in that plant alone, then we must note two other practical difficulties. The first is that the percentage of perfect goods produced indicates only that the rejected goods are not up to standard. It wholly avoids the subtle question of the degree of imperfection or the causes of rejection; which may be of considerable significance in the case of varying quality of raw material supply, changing skill of available labor, suitability of manufacturing equipment for the assigned work, or other factors beyond the management's control, in part at least.

The second of these difficulties is due to the fact that few plants make only one kind, model, size, or grade of product; and this is further complicated by changes in the relative proportions of productive capacity devoted to the various classes of product. Obviously the rating ratio used under these circumstances must be a weighted average, involving the application of excellent judgment.

Returning now to quality standards, for purposes of true measurement these standards should be invariable, definite, and uniform; but they are not, which fact alone should rule out the proposed ratio for comparing the management of one plant with that of another even in the same industry.

Quality of product is a combination of many separate factors, all of which are variable; so that no one article of output is exactly like any other. Manufacturing selects those quality attributes which together suffice to define completely the quality of the product for commercial purposes. It then seeks to confine the variations in each of these characteristic qualities within commercial limits. Consequently a complete quality standard should specify, in some definite form if practicable, the limiting deviations from the ideal standard which will be tolerated.

If the characteristic quality is one for which an accurate and generally accepted method of measurement exists, it is a practical matter to set up a general standard, as in the cases of dimension, strength, weight, composition, etc. However, if the quality in question is one for which no true method of measurement exists, the problem of defining a working standard is exceedingly difficult—for example, consider finish in metal goods; color in ceramics, textiles or paper; flavor and aroma in foodstuffs; and so on.

Furthermore, even in straight dimensional work in metals, another large source of difference enters the problem, namely, the method and instrumental means of measurement in use. Take the case of two plants making polished steel pins, say, 1 in. in diameter, with a specified tolerance of 0.0002 in. Plant A uses a fluid gage which is reset every hundred measurements, with a master which is checked by a measuring machine and Swedish gages each week. The pieces passed by such inspection will nearly always be within the tolerance. Plant B, on the other hand, uses a flat steel limit gage, and checks it occasionally by feel with a templet. It is likely that the pieces will exceed the specified tolerance by several times, with wide variations between different points in the same piece—depending, of course, on the method of manufacture in use. The inspection report of percentage perfect will probably be higher in plant B.

In any case judgment cannot be left out of the measurement of quality attainment, because judgment and quality go hand in hand. This is a major difference between quality and quantity of output. The latter is measurable with extreme accuracy, the former only with a good approximation when much care is used. Thus in the simple case of the pin just mentioned, finish is one of the important qualities present and is almost never measured—therefore judgment enters.

In like manner, even in a measured quality like dimension, there is always a certain proportion of the work produced which is not clearly "good" or "bad," but which is so close to the limits as to require the use of judgment. That is one of the important reasons for resorting to independent and unbiased inspection in grading

[1] Consulting Engineer. Mem. A.S.M.E.

[2] Presented at the Chattanooga Regional Meeting of The American Society of Mechanical Engineers, Oct. 23 and 24, 1923, and at the 1923 Management Week meetings.

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goods. The very presence of an inspection service is proof that quality must be judged in large part, and that only some work is measurable in such a way that there is general agreement that the work is or is not in accord with the standards. Thus, it is often possible to raise a quality standard over night by the simple expedient of putting the chief inspector on the grill.

From the preceding it should be clear that the author is very dubious about the practicability of measuring (in a strict sense) the quality attainment of management until there has been a decided advance in the application of inspection and related matters to the control of quality. Certainly any figure such as would be obtained in the ordinary factory today by applying the proposed rating ratio, would be very approximate indeed. But if approximate figures are resorted to they must be used with judgment, and if judgment is to be used in the last analysis, why not introduce it at the start? This procedure seems more justified than to use an arbitrary figure or method that will very likely deceive us. But is there really anything in science or in its engineering application, that excludes the use of trained judgment?

As a constructive substitute it is suggested that a critical examination of the following factors will give a sufficient, and certainly a more reliable, check on the quality attainment of a given management:

a Reputation for quality in the trade, to be checked by recent complaints from customers and by noting the standard and the degree of uniformity of current product.

b Calculated money loss in spoilage and seconds (which any adequate cost-system should reveal), checked in physical form by the size of the scrap pile and its rate of increase, and by lists of defective goods sold at a loss; and corrected for current and unavoidable difficulties introduced by some temporary trouble with new product, poor material, unskilled labor, unsuitable machinery, etc.

c Careful analysis in the factory of the adequacy of the methods in use for insuring a continuous and positive control of quality. Does inspection provide a filter to protect the factory against an influx of poor material, and does it prevent the shipment of defective product? Are the standards properly set and furnished to the shops in usable form? Are the inspection reports a reasonably true measure of the quality situation in each product class? Is a reasonable proportion of the actual product being made in conformity with said standards?

It is a serious question whether any practical advantage would result from an attempt to convert the above finding into figures. It is probable that more would be gained by putting the same energy into correcting the defects thus brought to light. Incidentally it is this quality approach to the management problem which reveals the surest way to produce more goods and better goods for less money; and after all is said, this is the reason we are discussing some possible method of measuring management.

In conclusion, the author would add that this critical discussion is not intended to detract from a laudable effort to develop a method for measuring management; but simply means that he does not see that any useful purpose will be served by adopting the proposed ratio nor, for that matter, any other method of computation which tends to substitute measurements for judgment, when the latter is more truly significant than the measured results.

Discussion

ROBERT G. COOK,[1] in a written discussion, said that a method to accurately measure the quality of a product was something very much desired and would be of considerable value to the industrial world could such a thing be accomplished.

As the author pointed out, the accurate analysis of the quality of goods passing merely the factory test was practically impossible mathematically. But, assuming an accurate record in this respect, developments over which the management apparently had no control, improvements made in a competitor's line, more severe tests in the field, failure of certain parts in use from causes heretofore not encountered, might necessitate the scrapping or making over of a large percentage of the stock. Here was a way the concern might get a reputation for poor quality no matter how perfectly its goods were produced in accordance with the factory standards. No matter how high an opinion the management might have of its own quality attainments, it was the public's opinion that counted. Quality in this respect could not be measured mathematically.

[1] Engineer, Ingersoll-Rand Co., Phillipsburg, N. J. Assoc-Mem. A.S.M.E.

Quality was a measure which did not cease functioning when the goods left the plant, but went on asserting itself for months or possibly years afterward, building up or tearing down the reputation of the concern responsible. Thus, it was Mr. Cook's opinion that the ratio under discussion gave a measure of only one phase of quality, and that phase was merely, as the numerator indicated, the proportion passing inspection.

Joseph W. Roe,[1] referring to Mr. Cook's discussion, said that the ratio presented in his paper on the Measurement of Management was not suggested as a measure of quality of the product. It was an indicating ratio of the quality of the management, with respect to the quality of product and not a final and usable ratio in itself. The suggestion in the original paper was that satisfactory ratios could be set up, of which this was one, which would be a guide in cases of further investigation.

The ratio did not tell anything about details, however, and the author's point in that regard was well taken. There were many things that would affect that ratio, but it was a good indicator and if one kept inside it, the result could not be very bad.

The author suggested that the customer's inspection be thrown out, because it was impossible to get it. Professor Roe would not do this, for he took it that the broad purpose of inspection was to determine whether or not the goods would serve the purpose for which they were intended.

In a broad sense the total number of rejections coming back to the plant, plus the total number in the plant, over the total of output, was, in general, like the quick-asset ratio in finance. If it was high and there were other problems to be dealt with besides that of management, then attention could be given to them. The ratio, emphasized Professor Roe, was as much a measure of the quality of the product as it was a measure of the quality of the management, in connection with its function, and was intended to serve merely as a red flag, to be used on the exception principle.

Hugo Diemer[2] said that by developing the reworking and salvaging departments better results might be obtained at less cost than if an attempt was made to have all the equipment and processing perfect.

D. S. Hartshorn[3] said that in his opinion quality in management did not depend entirely upon the quality of the goods produced. For instance, the question of excessive waste involved in the course of manufacture, reflected upon the quality of the management. In the plant with which he was connected a method of wage payment was employed that was not a factor in the so-called production by the workman. The good workman, although he might produce no more work than the average workman, still made considerably less waste, and this was reflected in his pay. He was also paid not only for the quantity and quality produced, but for continuity of service, and for the total length of time that he had been with the company. This had resulted in a labor turnover of less than 2 per cent annually.

W. O. Platt[4] said that the matter of applying the ratio in the foundry in order to pass the operations and do justice to the men, was a difficult problem and his company had never been able to get away from judgment in the building up of the ratio. It was, therefore, not a very accurate measurement, but they had made it useful by putting it on the bulletin board and letting the men themselves see about where they were standing with the work.

Frank B. Gilbreth[5] said that he had given the matter much thought, and believed that if one desired to have the best kind of management, and measured for that result, he would lay greater emphasis on the "why" in the changes in the ratio, rather than on the methods that made the ratio.

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[4] Pres., Jos. Reid Gas Engine Co., Oil City, Pa. Mem. A.S.M.E.

[5] Pres. Frank B. Gilbreth, Inc., Montclair, N. J. Mem. A.S.M.E.

SURVEY OF ENGINEERING PROGRESS

A Review of Attainment in Mechanical Engineering and Related Fields

Experimental Investigation of a Pneumatic Grain-Conveying Unit

NOTWITHSTANDING the great development of handling and conveying materials by pneumatic means, there have been very few complete and reliable tests carried out on actual installations. This is due partly to the fact that such a test would materially disarrange the operation of the plant, and also to the further fact that in a commercial plant it is very difficult to place the necessary instruments at a sufficient number of outlets to obtain reliable data. Nevertheless, the necessity for information as to certain values in the operation of a plant of this character became so pressing that a German concern, the Mühlenbau-Anstalt und Maschinenfabrik, vorm. Gebr. Seck, Dresden, was led to present for test purposes, a complete pneumatic grain-handling unit to the Machine Laboratory of the Technical High School in Dresden. The present article describes this installation and some of the work carried out on it.

The purpose of the series of tests undertaken was to determine the influence of the following factors: 1, The properties of the material handled, in particular its specific weight and the size, shape, and character of surface of the grain (the installation was especially devised for handling grain products); 2, the density and velocity of the air flowing, the energy of flow being determined by these two factors; 3, the direction of flow of the material handled, i.e., whether horizontal, upwardly inclined or vertical, and whether the changes in direction are brought about by the presence of bends; and 4, the magnitude of the diameter and the character of wall of the piping.

One of the aims of these tests was to gain an insight into the movement of the material handled, i.e., the path of the kernels in the pipe. In this connection it appeared to be advisable to start with the simplest possible experimental facilities, and, in the first place, to investigate the movement of a single ball in the pipe, and only after this had been done to attempt measurements on a regular flow of material. Of the many questions arising in this connection it proved to be possible to answer only the following two: 1, How great is the relative velocity between the stream of air and the flow of material in a long horizontal pipe? and 2, How does the material distribute itself over the cross-section of such a pipe and how does its velocity of flow vary between the wall and the center of the pipe?

In the first place, the author derives an equation for the flow of air in a pipe. He proceeds next to the discussion of the application of the law of dynamical similarity to work of the kind described here. The whole process of conveying has been divided into two partial processes, namely, basic turbulent flow of air in the pipe, and the motion of the material in the stream of air superimposed thereon. For the former of these processes the law of similarity establishes the necessary conditions (Reynold-Blasius), namely,

$$\frac{wd}{v} = \text{constant and } \rho = \text{constant} \qquad [1]$$

where w is the velocity of flow, d the diameter of the pipe, v the kinematic viscosity of the fluid, and ρ the relative roughness of the pipe (equal to the absolute roughness divided by pipe diameter). The movement of the material in the stream of air takes place under the influence of the following forces: 1, Gravitation acting on the material and fluid; 2, inertia forces of the material; 3, forces of fluid pressure which act at all points normally to the contact surface; and 4, surface forces resulting from the relative velocity of the air, these forces being (a) inertia forces in the stream of air and (b) frictional forces directed tangentially to the areas of contact acting in the viscous fluid. The forces enumerated under 3 and 4 are of the same character as the forces acting in any flow of a viscous liquid in a pipe. Equation [1] applies therefore to any body surrounded by a flowing liquid in so far as forces 3 and 4 are concerned. There are three other equations which hold good for this case and which are derived from the conditions of equilibrium between gravity forces, inertia forces, and forces of resistance; these may be derived from the elementary theory of these forces. Without going into this question further, the author points out, however, as a final conclusion that these four equations do not as a rule make it possible to satisfy all the conditions of dynamical similarity. Approximations such as are often permissible in model tests cannot be used here without neglecting material factors. Thus, for example, if one should desire to apply processes studied with air as the conveying fluid to a similar case with water, the specific weights of the materials handled would have to be changed in the ratio of the specific weights of the liquids. This is, however, practically impossible as the specific weights of air and water are in the ratio of 840, which would give such a specific weight of the material handled as to make the installation unworkable. Considerations based on the law of dynamical similarity are therefore subject to a very material restriction in the way of possible transfer of numerical values obtained in any series of experiments of that kind to the case of different liquids and different materials.

The installation, Fig. 1, was of the suction type, provided with reciprocating pumps acting as compressors and capable of consuming a maximum of 30 hp. The delivery capacity per hour was approximately 7000 kg. (1540 lb.) over an average distance of 150 m. (492 ft.). The installation had a total pipe length of 110 m. (360 ft.) with two side stretches of about 50 m. (164 ft.) straight and horizontal, connected by two bends, with a vertical section as shown in Fig. 1. The inside diameter of the pipe for the first 47 m. (154 ft.) is 89 mm. (3.5 in.), and from there on to the end, 95 mm. (3.74 in.).

The air from the atmosphere enters through the rounded nozzle b into an air-measuring pipe a, and flows thence through a valve e into an equalizer tank d having a capacity of 4.22 cu. m. (149 cu. ft.) and leading to the delivery pipe proper c. At the end of

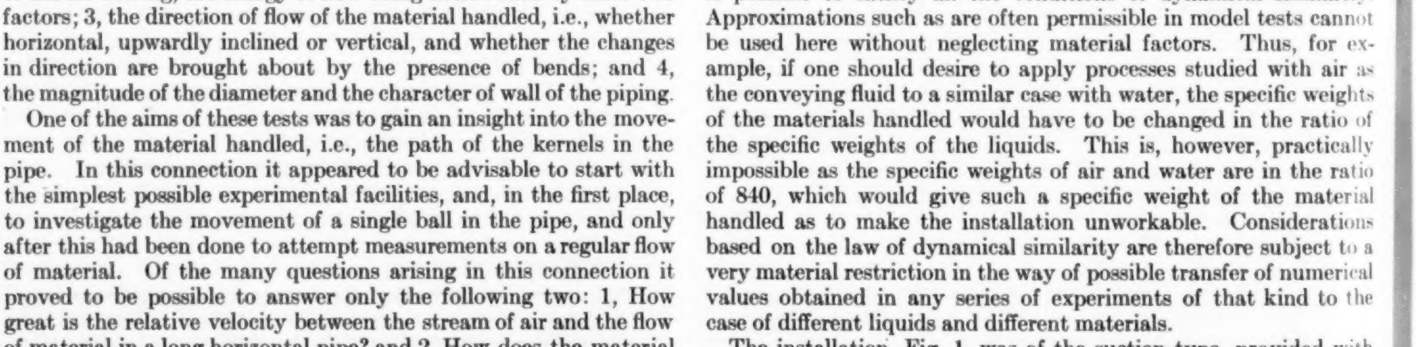

FIG. 1 LAYOUT OF THE EXPERIMENTAL INSTALLATION
(u = coils for measuring the motion of the test sphere; v = secondary winding; *rohrweite* = pipe diameter.)

this pipe there is a grain separator f, the air being taken from the upper part of this through a suction pipe g. The grain enters into pipe c at o. The original article describes the installation of the apparatus for the various measurements in detail, in particular for the measurement of air leakages as well as the experiments for the purpose of determining the method of movement through the pipes of a single small ball and a stream of grain. The present abstract reproduces only the main conclusions arrived at from the tests.

Pressure Drop in the Pipe with Air only Flowing and the Coefficient of Resistance

It would appear that the drop in pressure in the pipe and the coefficient of resistance are determined by the character of the surface of the pipe walls. This latter changes as a result of the conveying of the material, the pipe becoming smoother in course of time. Hence, before attempting any measurement of the drop in air pressure it was necessary to remove the rust and mill scale from the inside of the pipe in order to bring the surface to approxi-

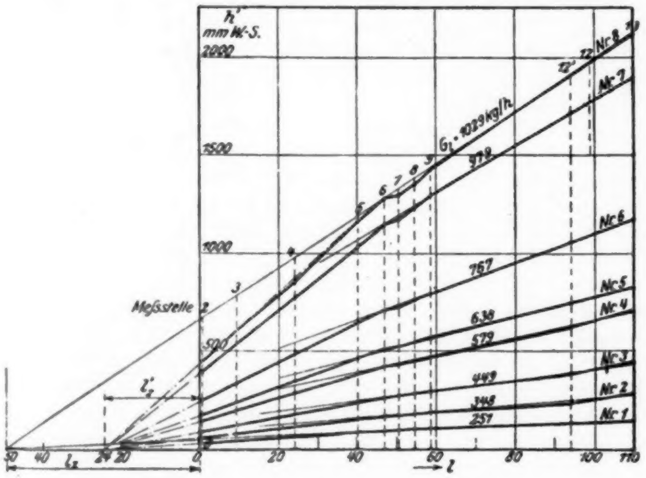

FIG. 2 CURVES OF DROP IN PRESSURE h' WITH AIR ONLY IN PIPE ALONG LENGTH l AT CONSTANT AIR VOLUME G_l

(*WS* = water column; *Messstelle* = measurement station.)

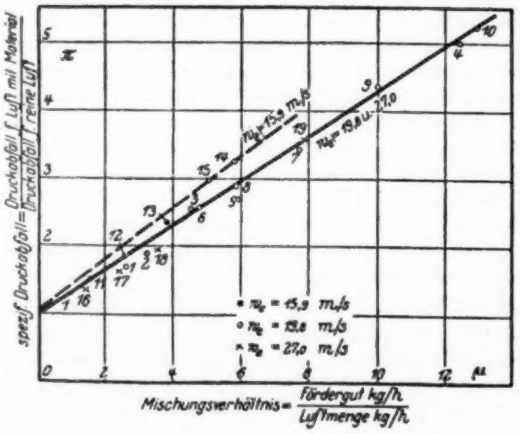

FIG. 4 SPECIFIC DROP IN PRESSURE π AS A FUNCTION OF THE MIXTURE RATIO μ

Ordinates: Specific drop in pressure = $\frac{\text{drop in pressure, air and material conveyed}}{\text{drop in pressure with air only}}$

Abscissas: Mixture ratio = $\frac{\text{material conveyed in kilograms per unit of time}}{\text{air in kilograms per unit of time}}$

mately the condition it would be in after a certain period of operation. For this purpose sharp-grained sand was sent through the pipe for several hours. The first measurements of pressure were then taken, after which a second batch of sand was sent through the pipe and another measurement taken, this latter showing that the pipe was practically smooth, as its coefficient of resistance did not materially differ from that determined by calculation with Jakob's constants for smooth pipes. In order to determine whether the character of the pipe had changed materially after a prolonged period of delivery of grain, two other series of measurements were carried out later on. Fig. 2 shows the drop in pressure in the pipe for various amounts of air handled. The bend at point 6 is due to the sudden change in the pipe diameter from 89 to 95 mm. (3.5 to 3.74 in.). In practice such an abrupt variation of diameter is adopted in order to take care of the expansion of the air in the pipe. Two other figures in the original article give curves showing the coefficients of resistance computed for the two diameters, and comparative data taken from Jakob's investigation on perfectly

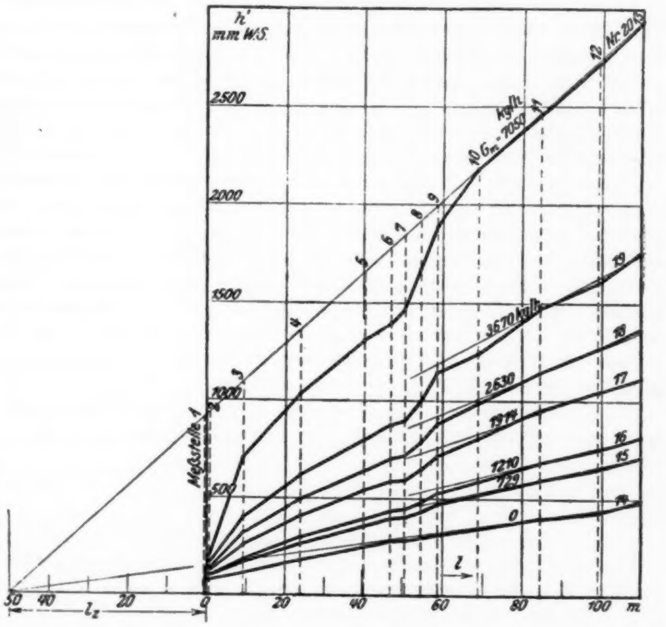

FIG. 3 DROP IN PRESSURE h' ALONG PIPE l FOR VARIOUS AMOUNTS G_m OF MATERIAL (WHEAT) DELIVERED; AIR VELOCITY w_e, 18.2 M. PER SEC.

(*WS* = water column; *Messstelle* = measurement station.)

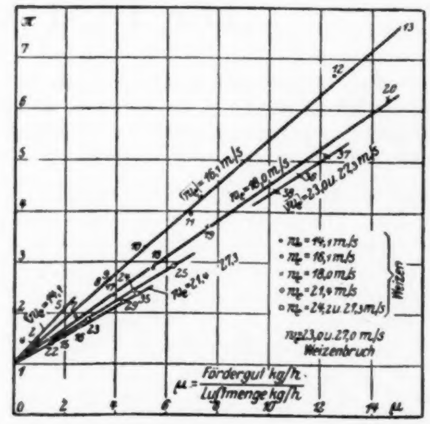

FIG. 5 SPECIFIC DROP IN PRESSURE π AS A FUNCTION OF THE MIXTURE RATIO

($\mu = \frac{\text{material delivered in kilograms per hour}}{\text{air in kilograms per hour}}$; *Weizen* = wheat.)

smooth pipes and another investigation on pipes of average roughness. (Complete references in the original article.)

Specific Drop in Pressure when Handling Grain

The purpose of these tests was to determine the influence of the mixture coefficient (weight of grain per hour divided by weight of air per hour) and the velocity of conveying w on the specific drop in pressure π in a pipe. Fig. 3 shows the results of a series of tests with wheat. Here the drop in pressure h' over the distance of delivery l is obtained at the constant air-suction velocity w_e at the inlet of 18.2 m. (59 ft.) per sec. for volumes of material varying from 0 to 7050 kg. per hr., and one recognizes the decided drop in pressure at the beginning of the conveying, i.e., during acceleration of the material. At the end of the first branch, measuring station

6, where the diameter of the pipe jumps from 89 to 95 mm. (3.5 to 3.74 in.) the pressure drop is pronounced and it increases still more in the bends and the uptake, stations 7 to 9. In the first section of the horizontal return pipe, stations 9 to 10, there is a certain amount of work of acceleration to be delivered and hence a correspondingly increased drop in pressure due to the fact that the material moves through the bends and uptake at a much reduced velocity. In this instance the total drop in pressure was reduced to terms of a horizontal pipe with constant diameter in order to eliminate for purposes of further investigation the manifold influence of the single stretches of pipe offering respectively greater or less resistance, and particularly in order to eliminate the influence of different diameters in the outgoing and return piping. To do this, the total straight piping and uptake, including the measuring stations, was replaced by an equivalent stretch of pipe l_{ae} of the diameter of the return piping 95 mm. (3.74 in.). If it be assumed that the pressure in a pipe containing only air decreases according to a straight-line law in proportion to the length of the pipe, the pipe being of constant diameter, a very simple graphic process may be used after the elimination of additional length of pipe for the reduction of the piping "as is" to piping of equal diameter. The details are set forth in the original article and the conclusion at which the author arrives is that for constant volumes of air G_l, the specific drop in pressure π is a linear function of the mixture ratio μ. The curves, which are all straight lines, are shown in the original article, and if α be the angle of inclination of the straight lines showing the specific drop of pressure, the latter may be expressed as follows:

$$\pi = 1 + \mu \tan \alpha$$

Figs. 4 and 5 would indicate that tan α is a function of the air velocity. The specific drop in pressure π is the higher the more that limit of velocity is approved at which it is still possible to convey material without having it deposited out of the air. This may be explained by the increase in contact between the material conveyed and the pipe walls, but as soon as with the increasing velocity of conveying the separation of the material conveyed out of the stream of air ceases, the influence of the velocity of conveying on the specific drop in pressure falls off very rapidly. In fact, at velocities in excess of 20 m. (65.6 ft.) per sec. the straight lines practically coincide (Figs. 4 and 5).

After having established this simple relation between the drop in pressure and the mixture ratio of material conveyed to air, the author proceeds to an investigation of the influence of the other variables, namely, air density, pipe diameter, and character of the material. The first subject discussed in this connection is the path of a single ball of material or a single kernel in the pipe.

In a vertical pipe the velocity necessary for moving a kernel bears a simple relation to its "floating" velocity. When a permanent state is reached the weight of the kernel less its buoyancy must be lifted by the forces arising from the relative velocity between the air and the grain. The following investigation is intended to determine whether a similar law applies to the movement of a kernel in a horizontal pipe. In order to obtain simple geometrical relations the tests were made with hollow spheres 7 to 20 mm. (0.28 to 0.79 in.) in diameter with specific weights varying between 0.8 and 3.0. The floating velocity of the test spheres was both calculated and determined experimentally, the original article giving the method of calculation. The experimental determination involved suspending the test sphere in a cylindrical pipe by a hair located exactly in the central axis of the pipe. Of course, this process cannot be used with very small spheres or bodies of asymmetrical shape, such as, for example, kernels of wheat, because in such cases the disturbances introduced by the suspension from the hair would make determination impossible. The floating velocity was determined by blowing the air and increasing the velocity in the pipe until the sphere began to dance. The results of these tests are given in the original article in the form of curves and involve the behavior of the test spheres at various air velocities and various air pressures (densities). (Doctor of Engineering Gasterstädt, Dessau, in *Zeitschrift des Vereines deutscher Ingenieure*, vol. 68, no. 24, June 14, 1924, pp. 617–624, 22 figs., *eA*)

The First World Power Conference

ONLY a very brief statement calling attention to a few of the papers presented at the Conference can be attempted here. The original Conference papers comprise several thick volumes and many thousands of pages of printed material.

The Complete Gasification of Coal is discussed by Prof. Hugo Strache, of Vienna. His paper deals in particular with a method of gasification wherein gas is generated direct from coal and represents a mixture of coal gas and water gas. It is claimed that it has a higher calorific value than water gas and is cheaper, as it is produced not from coke but direct from coal. The author calls this new kind of gas "double gas" and gives the following particulars. The yield of gas from 100 kg. of 7000-cal. coal is 156 cu.m., and the gross calorific power of 1 cu.m. at 0 deg. cent. and 760 mm. pressure is 3200 cal. (By complete gasification the author means gasification in which coke does not remain as residue.) Descriptions of the process of distillation and the machinery employed, together with the heat balance, are given in the original paper.

It is claimed that "double gas" is particularly suitable for delivery at distance of 40 to 200 km. (24.8 to 124.2 miles) because of its comparatively high heating value. (Section C, no. 111, 18 pp., 5 figs., *dc*)

Progress in Mechanical Engineering with Reference to Power Production in Austria. In the Francis turbine the desire to lead the water into the turbine in the most advantageous way, and to reduce as much as possible the space required for the machine, has led to a somewhat special arrangement: namely, a two-bearing set with horizontal shaft, the runner of the turbine being mounted on the extended shaft of the generator, and the bearing nearest to the turbine serving as a thrust bearing of double pressure in segments for withstanding the axial forces.

The greatest and most obvious progress achieved in the construction of water turbines in Austria is in respect to speed, the river conditions being particularly favorable for the application of propeller-type turbines. Experiments have shown the possibility of trouble due to cavitation, but this difficulty is said to have been overcome, for example, in the Siebenbrunn turbines, where, among other things, the regulation employed involves simultaneous adjustment of the stationary blades and the moving blades, this adjustment being effected by means of two servomotors, which, although separate, work together by the operation of a cam and by hydraulic control.

An interesting discussion of stop-valve design for superheated steam and for water-power pipe lines is included in the paper. (Section B, no. 75, 16 pp., illustr., *g*)

Hydroelectric Energy in France, M. Maroger. One of the interesting features of this paper is the part dealing with the methods used for coöperation between the electrochemical industry and hydroelectric power plants. The first cost of installation of water power in France is such that the base price per kilowatt-hour developed is in the majority of cases in excess of what the electrochemical industry can afford to pay. The power rates have been developed in such a manner that electrochemical plants get their current at a price below the book value. It appears, however, that this does not mean that other clients are taxed to support the electrochemical industry.

Another interesting feature of the French situation is the interlinking of water-power plants and steam plants. (Section B, no. 67, 10 pp., *g*)

General Data on the Propulsion of Ocean-Going Ships in Holland, W. J. Muller. The most interesting part of this paper is that dealing with Diesel-engined ships. Most of these belonging to Dutch owners have Werkspoor Diesel engines and Burmeister & Wain engines.

Two-stroke marine Diesel engines have not yet been tried in

Holland, though two passenger ships now in course of construction will both be equipped with Sulzer two-stroke Diesel engines.

The largest cylinders now in use are 740 mm. (29.1 in.) in diameter by 1150 mm. (45.2 in.) stroke, the maximum horsepower being about 1400 i.hp. per cylinder. From practical experience it is found to be safest not to exceed a temperature of 350 deg. cent. (662 deg. fahr.) of the exhaust gases, corresponding to a mean cylinder pressure of 6.25 kg. per sq. cm. (88.75 lb. per sq. in.) for four-stroke engines. (Section K, no. 327, 7 pp., *bc*)

Psychotechnics in Holland, J. K. Prak. The author admits from the start that psychotechnics is not a well-ordered tree of scientific knowledge, psychoanalytical examination of professional fitness being still in the stage of provisional orientation and tentative groping. The following are a few of the institutions using this method: The Municipal Psychotechnic Laboratory of Amsterdam examines municipal employees before they are engaged, such as taxi drivers, tramway drivers, electricians dealing with high-tension work, firemen, telephone operators, and policemen. The laboratory also examines those municipal employees who are suspected of neurasthenia or hysterical tendencies, or of physical or intellectual shortcomings.

Professor Roels conducted a preliminary examination on engineers, motor-car drivers, workmen at a factory making photographic paper, etc. In collaboration with army officers and at the request of the Secretary of War he devised a method of examining recruits, for which he adapted the mental tests in the American army to conditions in Holland. The same tests were used by Doctor Oort for the examination of over 1500 school children, and various groups of male and female nurses. The author describes an extensive investigation involving the selection of workmen suitable for metal work. (Section N, no. 413, 11 pp., *dg*)

Large Internal-Combustion Engines, G. F. Tosi. In submarines Diesel engines with outputs of from 2500 to 3000 hp. are used in order to obtain propelling aggregates of 5000 to 16,000 hp. These are very light engines, weighing 24 to 25 kg. (52.8 to 55 lb.) per b.hp. Special materials are employed, such as steel forgings for all lever portions, cast steel for castings, and aluminum for secondary details. Very special care is taken with these engines in connection with the cooling of various parts. As shown by photographs of liners and pistons of submarine Diesel engines, arrangements and ribbing are provided whereby the water and oil cooling is circulated at a high velocity to keep the walls of the combustion chamber from attaining dangerous temperatures. For high-powered Diesel engines of the single-acting type there are considerations which prevent a cylinder diameter being much greater than 800 mm. (31.49 in.) bore. Practice is now following that of the engine of 25 years ago, namely, employing the double-acting principle.

Three important European firms are developing a Diesel engine of more than 1000 b.hp. per cylinder: namely, Messrs. Tosi, Legano; Messrs. William Beardmore & Co., Ltd., Glasgow; and Messrs. Richardsons, Westgarth & Co., Hartlepool. This will be the largest double-acting marine engine built and will be of sufficient power to maintain a speed of 18 to 20 knots for transatlantic vessels of 20,000 tons with a propelling installation of 20,000 b.hp. on two shafts.

In engines of the double-acting type some builders have made an attempt to locate the cylinder between the connecting rods by adopting special rods, but it does not seem that this arrangement will become general. (Section E, no. 175, 7 pp., 2 figs., *dg*)

The Use of Steam Stations as Reserve on Hydroelectric Plants. In a paper entitled the Coexistence of Hydroelectric and Steam-Driven Generating Stations as Affecting the Economy of Production and the Necessities of Storage and Reserve, G. Motta, President of the Italian General Edison Electric Co. in Milan, comes to the conclusion that because of the variable delivery of water from Italian rivers, there is no other choice than to resort to the steam station as a means of maintaining an average uniform supply of electric energy, this method being preferable to the erection of large reservoirs for the storage and supply of water. (Section B, no. 73, 7 pp., *g*)

Alcohol as a Source of Power. This paper attempts to bring into prominence, with special reference to the British Empire, certain broad aspects of the problem in placing sufficient power alcohol on the market to supplement the waning supplies of gasoline throughout the world. The author believes that alcohol is the hope of the future in this respect. Suitable alcohol mixtures can be employed in existing types of internal-combustion engines which will give at least equally as good results as gasoline, and alcohol is already becoming an increasingly important factor in the fuel situation. The use of alcohol alone requires increased compression and carburetor adjustment, with modified throttling for starting up from the cold.

The author discusses sources of alcohol production, and mentions in particular the use of concentrated acids to obtain high yields, and efforts to produce alcohol by the action of various microörganisms on cellulose. In Great Britain individual companies are chiefly working on the development of new processes, and tropical countries present unusually favorable conditions for supplying alcohol.

Natalite is extensively used in Africa. It is a complete substitute for gasoline and is essentially a mixture of alcohol and ether, with the addition of some denaturing materials, which may be used alone or mixed with gasoline. The original article gives the volatilization curves of the various grades of natalite and complete information as to its use in internal-combustion engines. (Sir. Chas. H. Bedford, formerly Chemical Adviser to the Government of India. Section N, no. 417, 16 pp., illustr., *g*)

Application of Power to Air Transport. A very general discussion of the question of prime movers for aircraft. In the case of Rolls-Royce the engines are the 360-hp. Eagle and the 680-hp. Condor, and the overall weights per horsepower of these engines are 3.3 lb. and 2.8 lb., respectively. In the case of Napiers the engines are the 450-hp. Lion and the 1000-hp. Cub, in which the overall weights per horsepower are 2.9 and 3.1 lb., respectively. In the above weights have been included all accessories and adjuncts necessary for the functioning of the engine in the airplane, and in the case of the Condor and of the Cub there has been included the starter, which becomes an essential accessory for engines of such power.

The air-cooled static engine has now reached a high degree of excellence and reliability and deserves close consideration. Engines like the Jupiter, developing 400 hp., are lighter per horsepower than corresponding water-cooled engines by at least $^1/_2$ lb. per hp.

Air-cooled engines are cheaper, simpler, more accessible, and, for many purposes, such as work in hot climates, more suitable than water-cooled engines. For transport purposes, where the speed is not likely to be much over 100 miles per hour and where the primary consideration is ability to leave the ground with the maximum load per horsepower, the air-cooled engines at present available are at a disadvantage owing to the absence of reducing gear between crankshaft and airscrew. When getting up speed on the ground and during the initial climb the loss of efficiency on the direct-driven airscrew is such as to negative the decrease in the weight per horsepower of the engine. For the higher-speed military machines, this disadvantage is of less importance.

A reducing gear in an air-cooled radial engine may present mechanical difficulties owing to the somewhat wide variations of crankshaft torque, and there may also be some difficulty in obtaining the requisite flow of air over the cylinder heads, but there is no reason to suppose that these difficulties cannot be overcome.

With regard to the reliability of aircraft engines in general, it must be admitted that they are far more reliable than any one would expect, taking into consideration the extremely light weight, the multiplicity of parts and accessories, and the relatively flimsy structure forming the engine bed. The penalty for failure is so severe that designers and operators have succeeded in attaining some remarkable figures on mileage per mechanical breakdown. During the last twelve months, one of the companies has flown 289,000 miles and has had twenty-three landings due to mechanical failure, representing a distance per stoppage of over 125,000 miles, or halfway round the earth.

Coming to the question of the airplane itself, the author shows that the paying load per horsepower may vary from 3 lb. in a fast machine on a $3^1/_2$-hr. stage to 4 lb. with slower machines and shorter stages.

Put into the form of engine power per passenger, this means 60 hp. expended for every passenger carried, assuming a 100 per cent load factor, which is of course seldom the case. Compare

this to the $^1/_2$ hp. per passenger in an omnibus, to the 1 hp. per passenger in a train, and to the 5 hp. per passenger in a short-distance steamer of high speed, and some conception will be obtained of the heavy handicap against which air transport has to compete. A speed of 100 miles per hour is necessary in air transport to compete with wind and weather rather than with the 15, 50 or 25 miles per hour of the bus, train, or ship.

With these formidable facts in view it is remarkable that any hope is entertained that air transport can be established on a commercial basis. This is of course based exclusively on the existing state of development and does not consider possible aerodynamic improvements of the future.

The author views sympathetically the possibilities of the crude-oil engine for long-distance transport by airship, but he does not consider airships as a serious factor in air transport today. (Alec Ogilvie, Section K, no. 338, 19 pp., *g*)

Coke as Fuel for Steam Raising. In order to cater to the requirements of power stations equipped with coke-burning mechanical stokers, relatively cheap non-coking coal, which has hitherto been considered unsuitable, might profitably be used at gas works with the view of producing a friable coke or breeze that will not require cutting or grading. Such coal would be used in vertical retorts.

For use at power stations equipped with coke-burning mechanical stokers, coke breeze or coke of a friable nature is preferable.

Adapted to operate on this system, the stoker feed hopper is divided into two separate compartments, from which coal and coke in about equal proportions, are fed in superimposed layers, the coal being uppermost. The coal (which should preferably be low-grade small coal or slack) thus serves to ignite the coke as it enters the boiler furnace. The coal and coke are stored in separate overhead bunkers.

The potential outlet for coke in this direction is further instanced by the fact that by means of the sandwich system one London power station alone has, since 1918, consumed coke at the rate of 40,000 tons per annum, a quantity equal to about half its total fuel requirements. (W. L. Nicol, Engr. and Fuel Expert to the London Coke Committee, Section D, no. 136, 10 pp., *gd*)

Electrolytic Iron. Data on the processes of the LeFer Company in France, Eustis in America, and a Cheshire company in England.

The defects in electrolytic iron may be substantially of two kinds: (1) rough, uneven, spongy, and porous deposits; and (2) pitted deposits caused by so-called hydrogen craters.

The paper gives cost data on the process, with special reference to the one used in England.

Tubes produced under various conditions of operation and which all underwent a preliminary annealing were submitted to the National Physical Laboratory. The chemical analysis showed in one tube 0.031 carbon and 0.02 manganese. Under the microscope the material was found to consist of ferrite crystals of moderate size, of a structure typical of annealed pure iron; inclusions of impurities were also found. Thermal curves for the materials and data of various tests are given. (T. W. S. Hitchins. Section J, no. 292, 28 pp., 18 figs., *de*)

Fuel Economy and the Measurement of High Temperatures. The first part of this paper deals with the Federation of British Industries, which has established a special department to furnish manufacturers with technical advice and assistance on fuel questions and has a special economy committee. It has also published a fuel-economy review of an educational character.

The second part of the paper is devoted to a survey of fields where pyrometry has enabled accurate heat balances to be obtained, one of them being that of steam boilers. (Sir Robt. Hadfield, Hon. Mem. A.S.M.E. Section D, no. 135, 43 pp., illustr., *g*)

Gaseous Explosions within Closed Vessels. The author claims that the development of pressure within a closed vessel due to the combustion of a gaseous mixture is, in general, coincident with the spread of flame therein, so that, for example, except in special circumstances, the moment of attainment of maximum pressure corresponds with the moment of complete inflammation of the mixture.

The paper records the results of a study of the inflammation of different mixtures of pure methane and air, and pure ethane and air in closed spherical vessels. The principal data obtained were: (1) the maximum pressure developed; (2) the rates of development of pressure; and (3) the speeds of propagation of flame. Among other things were noted the effects of turbulence, it being claimed that under many conditions the action of turbulence is purely mechanical. The method of calculation of theoretical maximum pressures is given. (R. V. Wheeler, Section E, no. 172, 32 pp., 12 figs., *e*)

Steam Turbines. A general article by the originator of the Parsons steam-turbine type.

In the chapter devoted to an analysis of the present position, the author states that it is now well understood that in steam-turbine installations where steam economy is of prime importance, pressure compounding, or the placing of many simple turbines in series on the steam flow, is essential; so that one of the fundamental requisites for the attainment of high steam economy is the operation of the turbine at an appropriate overall velocity ratio, or ratio of mean blade velocity to steam-jet velocity. The question of high steam velocities versus moderate or low steam velocities is discussed to some extent, as well as certain other important features of design, the most interesting of which is that of regenerative feedwater heating as a method of increasing the mean temperature of heat reception.

As a second method of increasing the mean temperature of heat reception, an advance might be made if after superheat to the maximum temperature further heat might be added so as to maintain isothermal expansion throughout the initial stages of the turbine. This could only profitably be carried to such a point that subsequent adiabatic expansion in the turbine to the condenser vacuum would leave the steam just saturated. Such a method (of preliminary isothermal expansion) was proposed many years ago, but the mechanical difficulties in the way to its complete realization would appear insurmountable. An approximate solution, however, is being worked out at the present time; in some installations the steam, after a certain amount of expansion in the turbine, is extracted and raised again to a high temperature in a reheater before reëntering the turbine. Reheating has also the additional advantage of extending the range within which superheat exists and of diminishing the range where moisture and consequent loss by water resistance or increased viscosity exist. This process might of course be extended to include reheat at various stages of the expansion.

On the whole, the author believes that there are four methods of improving the thermal efficiency of the thermodynamic cycle without going to higher maximum temperatures: (1) Increased feedwater temperature, with regenerative heating of the feedwater by steam drawn from the turbines; (2) increased boiler pressure; (3) reheating of the steam after partial expansion; (4) increased vacuum, and means to utilize it effectively.

An application of these principles is made in the turbine plant of 50,000-kw. normal capacity to be erected in the new Crawford Avenue Power Station, Chicago, and now nearing completion at Newcastle-on-Tyne. In this plant there are three cylinders in series on the steam flow, each driving an alternator, the three alternators being electrically coupled in parallel.

Steam is generated at 600 lb. pressure and supplied to the stop valve of the high-pressure turbine at 550 lb. pressure, superheated to 750 deg. fahr. After expansion in the high-pressure turbine to a pressure of 100 lb. above atmosphere, it is led back through a well-lagged pipe into a reheater in the boiler house, from which it is returned to the intermediate-pressure turbine at a temperature of 700 deg. fahr. The high-pressure and intermediate-pressure turbines run at 1800 r.p.m. and drive alternators of 15,000 kw. and 30,000 kw. capacity, respectively.

Further expansion takes place in the intermediate-pressure turbine to a pressure of about 2.01 lb. absolute, at which pressure the steam enters the low-pressure cylinder, to be expanded to the condenser vacuum.

The low-pressure turbine drives a 5000-kw. alternator at 720 r.p.m. Owing to the lower revolutions of this turbine, the area provided in the final stage is so large that blades of normal profile, but set at a slightly greater discharge angle, can be employed. The steam is condensed in twin surface condensers with the tubes vertical and having a total surface of 56,000 sq. ft.

About 22 per cent of the total steam entering the turbine is used for feedwater heating; it is extracted from the turbines at three points, the feedwater being heated up from 65 deg. fahr. to 315 deg. fahr. in three stages before entering the economizers.

A heat consumption of 10,265 B.t.u. per kw-hr. is anticipated, or a thermal efficiency (from steam to electricity) of 33.2 per cent.

The blades throughout are of mild steel, formed integral with their roots by means of a new process developed in England. (Sir Chas. A. Parsons, Hon. Mem. A.S.M.E., Section D, no. 139, 21 pp., 5 figs., *dg*)

Short Abstracts of the Month

CORROSION

Corrosion—The Industrial Parasite

The entire issue of *Chemical and Metallurgical Engineering* for July 14 is devoted to a symposium on the subject of corrosion in the various chemical industries, such as the petroleum, gas-manufacture, fertilizer, zinc, and other industries.

One group of articles discusses the corrosive action of various substances, such as sulphuric, hydrochloric and nitric acids, ammonium nitrates, brines, etc., while another deals with various materials of construction, such as iron and steel, copper, aluminum, lead, nickel, tin and zinc, and briefly states their reactions toward corrosive materials.

The following statement on handling brine solutions containing calcium and magnesium chlorides may be of interest to mechanical engineers, because of the use of these solutions in refrigeration and in air drying and similar processes. The statement is due to L. A. Pridgeon, of the Diamond Crystal Salt Co., St. Clair, Mich.

Heaters that are used raise the temperature of the brine, under pressure, much above 106 deg. cent. These heaters are equipped with steel tubes. After drilling the scale off these tubes, the liberated carbon due to corrosion discolors the brine as black as ink. The attack on these steel tubes by the hot brine is many times greater than on steel pipes conveying cold brine.

A centrifugal pump installed for handling brine at 205 deg. fahr. was equipped with a steel shaft, cast-iron blades and a cast-iron body. After six weeks' use the shaft was attacked so badly that it was honeycombed for a depth of half an inch. The pump was replaced by one of all-bronze and it is still in service and does not show any signs of corrosion.

On cold-brine apparatus there is corrosion which may be due either to electrolysis or to corrosive sulphur gases in the brine. For instance, when an all-brass pump with a cast-iron head is used, the head is attacked. When the pump is all-brass the steel suction and discharge lines are attacked. Corrosion of steel brine lines has been reduced somewhat by attaching a bond or ground to lead off any stray electrical currents.

As for pipe lines, wrought-iron pipe stands up better than steel pipe, and cast-iron pipe better than wrought pipe. Many hot-brine lines become coated with a layer of gypsum, which tends to protect the metal from corrosion.

In the salt industry two bad effects come from corrosion of iron apparatus—the deterioration of the apparatus and the discoloration of the salt by the iron oxide. In open pans this last effect has been overcome by building the sides of the pan of Tobin bronze, and rakes and conveyors of bronze or monel metal.

General practice in handling brines is to have all pumps bronze or monel. Steel pipes and steel apparatus are used except for pumps on brine below 180 deg. fahr. Cast-iron pipes and cast-iron apparatus are found suitable for hot brine. Copper tubes are used for heaters and evaporators. In handling wet salt, brass, bronze, or monel metal is used. Driers are lined with monel metal or portland-cement mortar. All these precautions are taken, of course, to keep the salt from getting off-color by contamination with iron oxide.

The symposium is accompanied by a tabular presentation of chemical and physical properties of corrosion-resisting alloys and by a discussion of modern ideas on corrosion resistance. (*Chemical and Metallurgical Engineering*, vol. 31, no. 2, July 14, 1924, pp. 41–85, illustrated, *g*)

ENGINEERING MATERIALS

Strength of Steel Tubing under Combined Column and Transverse Loading

The purpose of the investigation described in this paper was to determine whether experimental data confirmed the theory of struts subjected to combined column and transverse loading. A number of tests were made on steel-tubing struts ranging from that of a column with no transverse load to that of a beam with no column load. Steel tubing made in England of $1^1/_2$ in. diameter, 20 gage, and $1^1/_2$ in. diameter, 16 gage, was used for all struts and beams in this investigation.

The results of this investigation warrant the following conclusions:

1 For determining the strength of a strut account must be taken of the effect of eccentricity. For steel-tubing struts the eccentricity resulting from (*a*) variation in wall thickness and (*b*) deviation from straightness are very important factors in determining the strength.

2 For struts subjected to combined column and transverse loading it is assumed that failure occurs when the maximum compressive fiber stress approximates the yield point of the material. The commonly used formulas which neglect the effect of eccentricity do not represent actual strut conditions and are not confirmed by experimental data. The use of these formulas for design purposes is shown by the data of this investigation to be inadvisable and possibly dangerous, especially for short struts or struts with small transverse loads.

3 A modified rational formula based upon consideration of the effect of eccentricity of loading was found to fit the experimental results very closely, the agreement being such as to indicate that it is the preferable formula for design where accuracy and safety are essential.

A method for a safe and reasonably accurate computation of stress for struts under transverse loading is offered in the paper. The results obtained by this formula are shown by the data to be on the average about 6 per cent too high, with the error on the side of safety. Certain recommendations are made. (Tom W. Greene in *Technologic Papers of the Bureau of Standards*, vol. 18, no. 258, May 23, 1924, pp. 243–279, 15 figs., *et*)

Development of a Method for Measurement of Internal Stress in Brass Tubing

Data of an investigation carried out at the Pittsburgh Experimental Station of the Bureau of Mines in connection with related metallurgical studies on brass.

A new method for the quantitative estimation of longitudinal internal stress in tube shapes—for example, cold-drawn brass tubes—showed that the major stress is longitudinal and that the stress in the outer part of the wall of the tubing is a longitudinal tensile stress, while that in the inner portion is a longitudinal compressive stress. The summation of the balanced stress, of course, is zero. Absence of circumferential stress in tubes is indicated by the failure of diametrically cut rings to spring in or out on being slit in two. Experiments showed that the unusual cutting methods which have been applied to bars and rods for the estimation of stress are not applicable to tubes, especially where the greater part of the stress is longitudinal.

The method described in the paper for measuring longitudinal internal stress is called the strip method, and consists of slitting a narrow strip longitudinally in a piece of tubing—for example, a strip 2.75 in. long and 0.10 in. wide in a 3.25-in. tube length—and then releasing one end of such a slit strip by cutting. Stress is indicated by the springing out of the freed end and can be calculated by a formula based upon the modulus of elasticity of the material and the distance in movement at the freed end.

The accelerating cracking agents were found to be of no value in detecting the presence of stress in certain lots of leaded brass tubing with cold reduction in area from 17 to 65 per cent.

Because a wrought brass does not crack under the application of an accelerating cracking agent, it does not follow that the material is free from internal stress.

Machining by Heyn's method failed to show length changes, that is, failed to disclose the presence of stress in the tubing investigated.

Cutting diametrical rings failed to show evidence of circumferential stress in the same tubing.

The stresses in some brass tubes have been shown to be only longitudinal, tensile, and compressive stresses.

The strip method, developed by the authors for detecting the presence of longitudinal internal stress, and for measuring quantitatively such stress in drawn brass tubes, can be applied in determining the laws governing the release of stress in cold-drawn internally stressed tubes on heat treatment. (Robt. J. Anderson, Metallurgist U. S. Bureau of Mines, and Everett G. Fahlman, Supt. of the National Smelting Co., Cleveland, O., in *Technologic Papers of the Bureau of Standards*, vol. 18, no. 257, May 23, 1924, pp. 229–241, 6 figs., *e*)

HEATING

Mercury Vapor as an Industrial Heating Medium

IN MANY processes where heating is a necessary operation the temperature required precludes the use of steam as a heating medium. Direct firing has been employed in such cases in the past, but this prevents maintaining close control of the process. The author of the article here abstracted presents an alternative for heating operations where (water) steam will not serve. This is the use of mercury vapor.

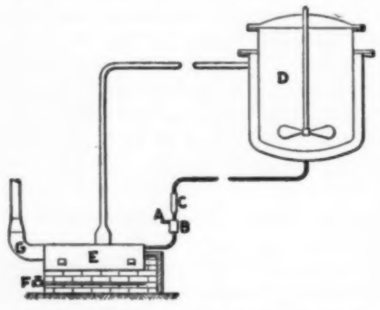

FIG. 1 APPLICATION OF MERCURY-VAPOR HEATING TO A STILL

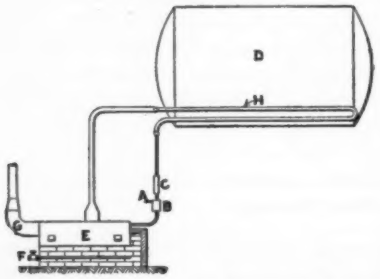

FIG. 2 APPLICATION OF MERCURY-VAPOR HEATING TO A SULPHONATOR

The author states that the first commercial installation of a mercury system of heating, cooling, and temperature control was successfully operated in 1915, and that there have been to date twelve installations aggregating 650 boiler hp. A list of these is given. The range through which mercury-vapor heating is most effective is from 180 deg. to 500 deg. cent. (356 to 932 deg. fahr.). In its simplest form the mercury heating system is shown in Figs. 1 and 2. The boiler *E* is mounted in a brick setting and contains the mercury. It is heated by any means such as oil or gas controlled by the value the waste gases passing up the stack *G*. The mercury vapors, delivered by the boiler, flow into the jacket of the vessel to be heated *D*, the condensate returning through the cooler *C* and separator *B* to the boiler for reëvaporation.

The control of the system is by means of the pressure exerted upon the boiling mercury. A vacuum or pressure connection *A* is made to the separator and by controlling this pressure it is possible to raise or lower the temperature 50 or 100 deg. within a few minutes. In actual installation a mercury boiler of a special design is used. It is of very small size in proportion to the vessel being heated which is due to the high heat-transfer properties of mercury. A feature of the mercury system which has been worked out successfully is the maintenance of temperature in an exothermic reaction. This is done by surrounding the vessel with a jacket of liquid mercury boiling at a temperature predetermined and controlled by regulating the pressure in the jacket. In other installations coils containing liquid mercury may be installed in the vessel in lieu of a jacket and the control of the temperature of vaporization is obtained by controlling the vapor pressure of the mercury being boiled.

The advantages of this system of heating, cooling, and temperature control may be briefly summarized as follows: Effective temperature control, elimination of hazard, any required temperature up to 500 deg. cent. (932 deg. fahr.), low installation cost, low operating cost, low maintenance cost, immediate "pick up" from one temperature to another, small building space, high heat transfer, high effective temperature drop available, simple attachment to any type of apparatus, can use any source of heat as oil, gas, coal, or electricity, no overheating possible, quick addition of heat, quick abstraction of heat, simplicity or operation—little or no attention, operating data available for design of new installation. (Crosby Field, Mem. A.S.M.E., Vice-Pres. Chemical Machinery Corp., New York, N. Y., in *Chemical and Metallurgical Engineering*, vol. 30, no. 25, June 23, 1924, pp. 987–991, 8 figs., *d*)

INTERNAL-COMBUSTION ENGINEERING (See Motor-Car Engineering)

MACHINE SHOP (See Testing of Materials)

MECHANICS (See Engineering Materials)

MOTOR-CAR ENGINEERING

Rickenbacker Vertical Eight

THE first concern to put a straight eight-cylinder motor car on the American market was the Packard Company. Since then the Jordan and the Rickenbacker Companies have begun to build eights, and the Studebaker Company is understood to be doing the same, as well as two or three other companies mentioned.

The Rickenbacker eight is in some respects essentially different from all the others. The two features of special interest are the camshaft construction and the cylinder arrangement. As regards the former, the camshaft is located in a compartment separate from the crankcase where it is completely immersed in oil at all times. This is different from the usual American practice where the camshaft is oiled by the spray from the crankshaft and rod bearings.

As regards the engine itself, it is divided into two practically independent sets of four cylinders. It has a double carburetor with two feed tubes from the fuel tank to the vacuum system. Each half of the carburetor operates its own set of four cylinders, the ignition in the two sets being likewise independent of each other as to sequence. The manifolding to each four is made separate to prevent overlapping, both the inlet and exhaust manifolds being arranged as if for two independent fours. A blind chamber is provided into which the hot gases can enter but from which there is no outlet. The theory advanced for this is that, inasmuch as hot gases will readily enter from below a compartment filled with cold air, heat will accumulate in the chamber at first rapidly and then more slowly, until a state of equilibrium is attained. The gas then imprisoned tends to keep out additional gas. Thus when the engine is started cold the intake passages are rapidly heated to the desired degree, and thereafter heat is absorbed much more slowly.

From the independent manifolds for the inner and outer fours the gases pass through two exhaust pipes to a dual muffler in a single housing, so that the eight really exhausts as two fours. (J. E. Schipper in *Automotive Industries*, vol. 50, no. 26, June 26, 1924, pp. 1369–1372, 4 figs., *d*)

Car Carburation Requirements

ANALYSIS of car performance with the purpose of establishment on a flow-rate basis the desired metering characteristics of a carburetor for level-road operation.

The author comes to the following conclusions:

Engine. (*a*) Engines in good mechanical condition have the same mixture requirements. (*b*) Mixture requirements of an engine vary with load but not with speed. (*c*) At all fractional loads maximum economy is reached at the lean limit of inflammability; this lean limit is not changed by engine speed. (*d*) Acceleration represents the reserve power available; it is a high-load condition and requires a high-power mixture. (*e*) Manifolding to secure adequate vaporization and correct distribution is a prerequisite to correct carburation and is assumed in this analysis.

Car. (*f*) The demands of an automobile on its engine (load factor) are determined by car weight, gear ratio, wheel diameter, tire

characteristics, road conditions, and frictional (wind) resistance of the car. These in conjunction with engine size establish the demands of the carburetor. (*g*) Cars of the same weight may require the same mixture ratios of fuel and air, but differing gear ratios and other factors will make the flow rates different at the same speed; thus each car may have its individual level-road mixture requirements even though the engine requirements are common. (*h*) Operation on smooth, level road requires richer mixtures than any other running conditions except idling, acceleration, and wide-open throttle. Therefore a carburetor designed to meet these conditions will give the greatest practical economy.

Carburetor. (*i*) In the ideal carburetor, engine load would be recognized in addition to air-flow rate. However, level-road metering requirements can be obtained on a flow-rate basis. (*j*) A positive enrichment for acceleration and for open-throttle running is essential. (*k*) The utmost a carburetor can do for a car is to enable the engine to develop its inherent economy, and that without limiting its capacity to permit the engine to operate at its maximum thermal efficiency under any fractional load. (*l*) The mixture requirements of a car are dependent on the load factor imposed on the engine by the car design, so that each car and engine combination requires a carbureting system specially designed for its needs. (C. S. Kegerreis and O. Chenoweth in *Bulletin of Purdue University, Publications of the Engineering Department*, vol. 8, no. 4, May, 1924, 19 pp., 7 figs., *et*)

PHYSICS

Falling Drops

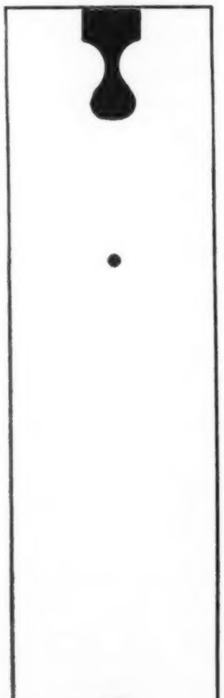

Fig. 3 Photographs of a Drop in the Process of Formation and While Falling

The term "drop shape" has come to signify in aeronautics that shape which gives a body the least air resistance (equivalent to what is known as streamline shape). The idea that a falling drop is essentially of that shape is extremely common.

Engineer Jaray, the builder of the streamline automobile named after him, was the first to prove that falling drops do not have a streamline shape but are essentially spherical. This he has shown both theoretically and experimentally. In the course of this investigation he has made use of photographs of falling drops, one of which is reproduced in Fig. 3. In this the upper part of the figure shows a drop of a black liquid ready to fall away from a capillary tube. It is the shape of the globe of liquid here—which is not yet a real drop—that has probably created all the confusion as to the shape of true drops. This shape differs, however, very materially from a streamline shape and has absolutely nothing to do with air resistance. Next one sees a freely falling drop in the process of flattening out in the direction of fall as a result of pulsations. In between them is a little droplet which was formed when the large drop broke away from the end of the tube. This is probably spheroidal. (E. Mayer in *Der Motorwagen*, vol. 27, no. 15, May 31, 1924, pp. 264–265, 1 fig., *e*)

POWER-PLANT ENGINEERING

Wabash River Mine-Mouth Plant of the Indiana Electric Corporation

Description of the first section of a 40,000-kw. plant for which present tentative plans call for an ultimate capacity of 100,000 to 200,000 kw. Only some of the features of this extensive article can be noted here.

To any one who has followed the trend of power-plant engineering the constant decrease in the ratio of the size of the station to the capacity is quite marked. Such a statement unsupported by any other facts might lead one to suppose that modern stations were exceedingly cramped for room; such, however, is far from being the case. The first impression one gets in visiting such a plant is the amazing size of the place. There seems to be boundless room everywhere, all around and overhead. The firing aisle is wide, but no wider than is necessary to accommodate the weigh larry; the aisle behind the boilers is also wide, but only wide enough to replace tubes; the space around the turbines is ample, but only sufficient to accommodate the condensers and auxiliaries below. And so it goes; there is plenty of space, but it all serves a definite and useful purpose. The reason for this small ratio lies not in cramping the equipment but rather in the extreme compactness of the units themselves.

The station is to be supplied eventually with fuel from coal strata underlying the company's property, though at present coal from an outside source is used.

The present boiler installation consists of four Babcock & Wilcox cross-drum-type boilers, each having 17,260 sq. ft. of heating surface, which are operated at 350 lb. pressure. Each boiler contains 720 tubes 4 in. in diameter by 20-ft. long, arranged in 36 sections, each section containing 20 tubes. The high tube banks were used rather than shorter bank in connection with an economizer because the comparatively low cost of the coal did not justify the use of economizers with their increased maintenance costs. As indicated on the cross-sectional drawing of the boiler, the lower two rows of tubes are segregated from the others so as to form a kind of slag screen which provides ample entrance area for the gases of combustion, to prevent the adherence of clinker and slag.

In the section of the plant just completed the turbine room contains two 20,000-kw. single-cylinder Westinghouse combination impulse- and reaction-type turbo-generators. These units take steam at a pressure of 200 lb. and a temperature of 650 deg. fahr. Both units are arranged for bleeding steam for feedwater heating from the third and fourth blade rings. At rated capacity approximately 25,400 lb. of steam per hour is extracted for this purpose, this quantity being sufficient to heat the condensate to an average temperature of 208 deg. fahr. as measured at the discharge of the second or higher-pressure meter.

Because of the uncertainty of the long-distance telephone service under adverse weather conditions, elaborate means have been provided for maintaining communication between stations. The load dispatcher's room is provided with a Westinghouse duplex carrier-wave telephone system, by means of which the dispatcher can talk to any plant on the system. By means of this system radio frequencies, modulated by voice currents, are superimposed on the high-voltage transmission frequencies through capacity coupling between the transmission line and an aerial about 1000 ft. long strung immediately above. The radio-frequency waves are thus transmitted along with the power waves to a similar capacity coupling at the receiving end. Each station on the system has two aerials, one for sending and one for receiving. They may both be operated simultaneously, a feature which permits the dispatcher to talk and listen at the same time, i.e., just as in an ordinary telephone conversation. (*Power Plant Engineering*, vol. 28, no. 13, July 1, 1924, pp. 682–692, 10 figs., *d*)

Prime Movers Committee Reports

Stacks and Flues

Data of an investigation carried out to ascertain how closely in practice the actual draft obtained in the chimneys of various power plants checked with the theoretical values given by the most modern methods.

From the results obtained, the definite conclusions reached are: (1) The present method of computing stack draft does not take into account all the factors involved when the condition of flow gases exists. (2) Stacks should be designed for conditions actually obtaining in practice. (3) Additional data as to stack conditions at various points of the horizontal cross-section and at several elevations must be procured. (4) These new data may enable the definite computation of several factors which affect the draft when gases are flowing.

In connection with this it was noted that with all the boilers

connected to a stack there was a rather definite relationship between the carbon dioxide in the stack gas and the rating of the boilers. (Paper no. 24-3, Feb., 1924, 3 pp., 1 fig., *e*)

Design and Maintenance of a 1500-Kw. Central Station Plant

This paper is not suitable for abstracting, but is recommended to designers of power plants and students of power-plant engineering. (Paper no. 24-1, Feb., 1924, 21 pp., 30 figs., *dA*)

Power-Station Heat Balance

This paper really deals with trend of tendencies in power-station design in 1923. The following abstract is taken from the original publication.

Present sources of auxiliary power for steam-electric generating stations include that obtained from house turbines and from main units, with some tendency toward the auxiliary generator driven by the main unit. An investigation made of a number of power stations being built or extended in 1923 indicates a definite trend toward motor-driven auxiliaries, with the principal exception of boiler-feed pumps.

Bleeder heaters have been generally incorporated in the design of power stations built in 1923. There are various methods of incorporating these heaters into power-station layouts as numerous flow diagrams attest. The results obtained by an increase in the number of bleeder heaters well illustrate the economic "Law of Diminishing Returns." Superheated steam seems to act as saturated steam in heaters.

The variation in the capacity of the many types of evaporators on the market is affected by their source of steam and condensing water. Marine and land evaporators in general differ. To obtain maximum capacity of evaporators with a minimum of coil cleaning, frequent cracking or reversals are necessary. The emergency capacity of evaporators may be increased by various means. Flow diagrams indicate many ways to introduce evaporators into the heat-balance system.

The adoption of a closed condensate system has decreased the amount of oxygen in the condensate to such a low mount as to allow a simplification of deaerator arrangement resisting in several new designs. With this reduced oxygen content, it is often possible to change the plant heater into a deactivator delivering practically oxygen-free water. Deaerators may be worked into plant layouts in many different ways.

Several power stations have successfully incorporated-air coolers and turbine- and transformer-oil coolers into their heat-balance schemes. In a plant equipped for stage bleeding, only a slight heat saving is obtained by the use of generator-air coolers, compared with obtaining the same temperature by further extraction of steam from low levels; generator-air coolers are, however, generally installed for other reasons.

Promising results have been obtained from their first test of flue-gas air preheaters. One power station is installing extraction-steam air preheaters.

Experience with high-speed single-stage boiler-feed pumps has been most satisfactory. Several manufacturers are now making pumps with speeds in the neighborhood of 4000 r.p.m.

The greatest improvement in small turbines has been in the modification of the governors to render them more powerful, and hence more satisfactory in performance, especially with high-temperature steam.

Through the coöperation of the Generator Stations Subcommittee of the Electrical Apparatus Committee, a study of the function rather than the details of electrically driven power-station auxiliaries has been undertaken. Motors of different types are available to meet the characteristics of the drivers demanded for various auxiliaries. Duplicate motors on some of the more important drivers result in greater reliability and reduced low-load losses. Progress is reported by one company in the adaptation of automatic control to electrically driven boiler-feed pumps and induced- and forced-draft fans.

The installation of bleeder heaters is often advantageous in the revamping of old power stations.

In conjunction with the report on Small Prime Movers, a method of obtaining the heat balance of a plant containing two 2500-kw. units is presented, which indicates the advantage of one or two levels of steam extraction with motor-driven auxiliaries over steam-driven auxiliaries.

A theoretical study discusses the effect on plant economy of stage bleeding and air preheating by waste gases and steam extraction, as well as showing the effect on capital cost. (Paper no. 24-50, May, 1924, 93 pp., 91 figs., *dA*)

SPECIAL MACHINERY (See Transportation and Handling of Materials)

TESTING OF MATERIALS

A Method for Determining the Resistance of Metals to Drilling and Its Application to the Investigation of the Machinability of Metals

The resistance which a metal offers to machining by cutting tools, according to a joint investigation of the author and Prof. Dr. Heyn, depends not only on the hardness but also on the plasticity of the

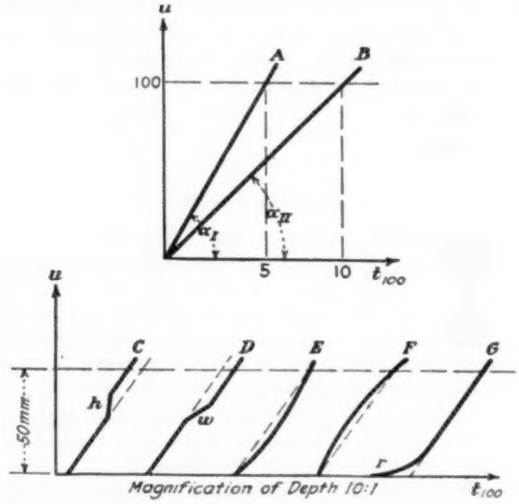

Fig. 4 Autographic Record of Drilling-Machine Test

material. Hardness has been defined as the resistance which a body offers to the penetration by another, harder body. Plasticity is the ability of a body to undergo dislocation of its smallest structural particles, as a consequence of the application of external forces, at ordinary temperatures, without disturbance of their coherence. The resistance which a material offers to penetration by a cutting tool is due to its hardness and plasticity; the "machinability" of the material depends upon the combined effect of these two characteristics.

For determining the resistance to penetration by cutting tools, the author devised a drilling testing machine. In this a numerical value for machinability is established by using a drill as a cutting tool and measuring the drilling depth obtained by 100 revolutions of the tool. The test is based upon the consideration that for a definite load the depth of drilling obtained by a definite number of revolutions may be greater in proportion to the better machining qualities of the material under investigation.

The recording pencil automatically draws a diagram the ordinates of which are the number of revolutions of the drill and the abscissas are drilling-depth values. If the material under investigation is homogeneous and its thermal conditions remain constant, the autographic record will be a straight line. The angle α which this line forms with the horizontal (Fig. 4) is a measure of the machinability of the material under test, and material *A* is seen to be twice as difficult to machine as material *B*.

Material *C* shows a hard spot at *h* and material *D* a soft spot at *w*, while material *E* becomes harder toward the inside and material *F* softer. In the curve *G*, the curvature *r* represents the initial attack of the drill, i.e., the vertical travel which must be traversed in every test until both cutting edges of the drill are in effect over their entire length.

The angle of inclination of the straight record line or of the straight

line drawn to connect the starting and end points of the curves represents the value of the machinability of the material. Since, however, the measurement of this angle may introduce an error, the actual depth of the hole drilled by 100 revolutions can be taken as measure of this property (assuming that all external conditions such as load on drill, revolutions, diameter of drill, cutting edges and all angles, remain constant).

The drilling testing machine is described in the original article together with certain investigations carried out by means of it, such as ball penetration and machinability of brass with increasing lead content; influence of silicon content on the machinability of cast iron; influence of speed of cooling on machinability and ball-penetration hardness of cast iron.

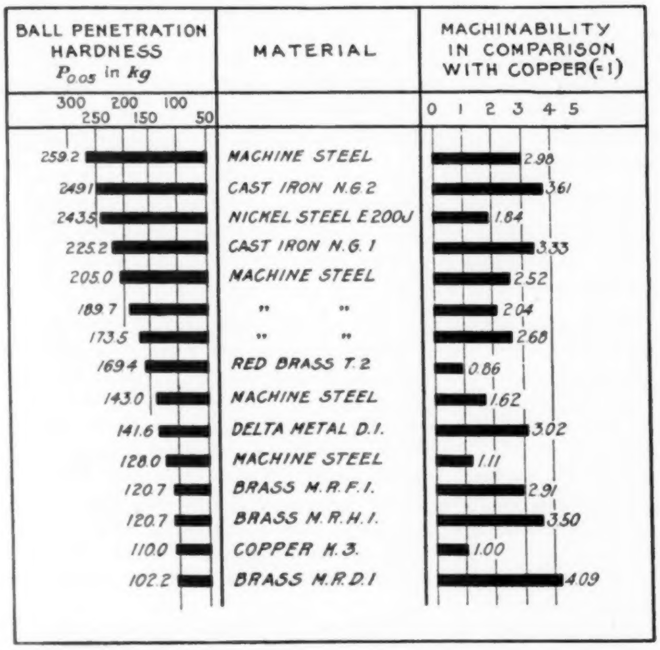

FIG. 5 BALL-PENETRATION HARDNESS (MARTENS-HEYN UNITS) AND MACHINABILITY OF VARIOUS METALS AND ALLOYS

Since the drilling test does not yield absolute values but only comparative ones, the author endeavored to find by means of an extended series of tests a metal which would serve as a standard of comparison to which other metals could be brought into relation.

For individual shops it is sufficient if they take as standard of comparison any homogeneous alloy they please that is easily accessible in fairly large quantities, and if they calculate all drilling tests on a basis of comparison with that particular alloy. The particular alloy chosen may again be compared from time to time with rolled and annealed electrolytic copper, so as to bring the shop tests into relation with tests made in scientific research institutions, which would use the latter material. In the numerous tests undertaken in the laboratories of the Deutsche Maschinenfabrik A. G., a "hollow drill steel" of the following analysis was used for the purpose of a comparative standard: C, 0.85; Si, 0.05; Mn, 0.26; P, 0.035; S, trace. This material had a Brinell hardness of 207 at 3000 kg. load on a 10-mm. ball.

Fig. 5 shows numerically and graphically values of ball-penetration hardness and machinability of a number of metals and alloys. The various materials are arranged according to their ball-penetration hardness, starting with the hardest metal investigated. Against these hardness values—shown at the left—the values of machinibility expressed in their ratio to that of copper (taken as unit of 1) are shown at the right. This graphic representation shows, for instance, machine steels of different strength and hardness and verifies the statement previously made that of two metals of equal strength the one possessing greater ductility is that which is the more difficult to machine. The particularly ductile metal copper, with a hardness of 110 kg., was taken as a comparative standard and its machinability to be unity. Nearly all the other metals investigated were easier to machine than copper (i.e., possessed a higher machinability), particularly brass, delta metal, cast iron, and the steels of greatest strength. (Prof. Dr. A. Kessner, Charlottenburg, Germany, in *Testing*, vol. 1, no. 4 April, 1924, pp. 270–285, 11 figs., *d*)

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To show how few rollers are required for the magnetized roller type as compared to a standard form of the mechanical type, the author takes as an example a conveyor 150 ft. long for finished bar. For a standard type of mechanical conveyor, there would be required approximatly 38.8-in. rollers, located on 4 ft. centers. To support and drive these rollers, 114 bearings and 76 spiral or miter gears would be needed. A magnetized roller conveyor to do the same work would require six 4-in. rollers in sets of two rollers, each set of rollers being located on 50-ft. centers. The number of bearings required would be 18 and the number of gear wheels 15, of the simple spur-and-pinion type. With the smaller number of rollers to be accelerated, the horsepower of the driving motor would be at least one-half that required by the mechanical type.

On the 10-in. central bar mill, three sets of magnetic rollers are used on a conveyor 150 ft. long. Each set of rollers is driven by a 2-hp., 1-hr. mill rating, compound-wound d.c. motor. The motors are geared to the rollers to give a bar travel of about 250 ft. per min., and on a 10-hr. turn this mill has turned out approximately 100 tons of $^{19}/_{32}$-in. spike iron, or an average of 10 tons of iron bar per hour, which the conveyor was called up to handle. These bars are generally conveyed eight at a time, and no trouble has been experienced in keeping the cooling bed clear of iron. (Harry Holles, Elec. Supt., Bethlehem Steel Co., Sparrows Pt., Md., in *Iron and Steel Engineer*, vol. 1, no. 5, May, 1924, pp. 248–249, 3 figs., *d*)

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connected to a stack there was a rather definite relationship between the carbon dioxide in the stack gas and the rating of the boilers. (Paper no. 24-3, Feb., 1924, 3 pp., 1 fig., *e*)

DESIGN AND MAINTENANCE OF A 1500-KW. CENTRAL STATION PLANT

This paper is not suitable for abstracting, but is recommended to designers of power plants and students of power-plant engineering. (Paper no. 24-1, Feb., 1924, 21 pp., 30 figs., *dA*)

POWER-STATION HEAT BALANCE

This paper really deals with trend of tendencies in power-station design in 1923. The following abstract is taken from the original publication.

Present sources of auxiliary power for steam-electric generating stations include that obtained from house turbines and from main units, with some tendency toward the auxiliary generator driven by the main unit. An investigation made of a number of power stations being built or extended in 1923 indicates a definite trend toward motor-driven auxiliaries, with the principal exception of boiler-feed pumps.

Bleeder heaters have been generally incorporated in the design of power stations built in 1923. There are various methods of incorporating these heaters into power-station layouts as numerous flow diagrams attest. The results obtained by an increase in the number of bleeder heaters well illustrate the economic "Law of Diminishing Returns." Superheated steam seems to act as saturated steam in heaters.

The variation in the capacity of the many types of evaporators on the market is affected by their source of steam and condensing water. Marine and land evaporators in general differ. To obtain maximum capacity of evaporators with a minimum of coil cleaning, frequent cracking or reversals are necessary. The emergency capacity of evaporators may be increased by various means. Flow diagrams indicate many ways to introduce evaporators into the heat-balance system.

The adoption of a closed condensate system has decreased the amount of oxygen in the condensate to such a low mount as to allow a simplification of deaerator arrangement resisting in several new designs. With this reduced oxygen content, it is often possible to change the plant heater into a deactivator delivering practically oxygen-free water. Deaerators may be worked into plant layouts in many different ways.

Several power stations have successfully incorporated-air coolers and turbine- and transformer-oil coolers into their heat-balance schemes. In a plant equipped for stage bleeding, only a slight heat saving is obtained by the use of generator-air coolers, compared with obtaining the same temperature by further extraction of steam from low levels; generator-air coolers are, however, generally installed for other reasons.

Promising results have been obtained from their first test of flue-gas air preheaters. One power station is installing extraction-steam air preheaters.

Experience with high-speed single-stage boiler-feed pumps has been most satisfactory. Several manufacturers are now making pumps with speeds in the neighborhood of 4000 r.p.m.

The greatest improvement in small turbines has been in the modification of the governors to render them more powerful, and hence more satisfactory in performance, especially with high-temperature steam.

Through the coöperation of the Generator Stations Subcommittee of the Electrical Apparatus Committee, a study of the function rather than the details of electrically driven power-station auxiliaries has been undertaken. Motors of different types are available to meet the characteristics of the drivers demanded for various auxiliaries. Duplicate motors on some of the more important drivers result in greater reliability and reduced low-load losses. Progress is reported by one company in the adaptation of automatic control to electrically driven boiler-feed pumps and induced- and forced-draft fans.

The installation of bleeder heaters is often advantageous in the revamping of old power stations.

In conjunction with the report on Small Prime Movers, a method of obtaining the heat balance of a plant containing two 2500-kw. units is presented, which indicates the advantage of one or two levels of steam extraction with motor-driven auxiliaries over steam-driven auxiliaries.

A theoretical study discusses the effect on plant economy of stage bleeding and air preheating by waste gases and steam extraction, as well as showing the effect on capital cost. (Paper no. 24-50, May, 1924, 93 pp., 91 figs., *dA*)

SPECIAL MACHINERY (See Transportation and Handling of Materials)

TESTING OF MATERIALS

A Method for Determining the Resistance of Metals to Drilling and Its Application to the Investigation of the Machinability of Metals

THE resistance which a metal offers to machining by cutting tools, according to a joint investigation of the author and Prof. Dr. Heyn, depends not only on the hardness but also on the plasticity of the

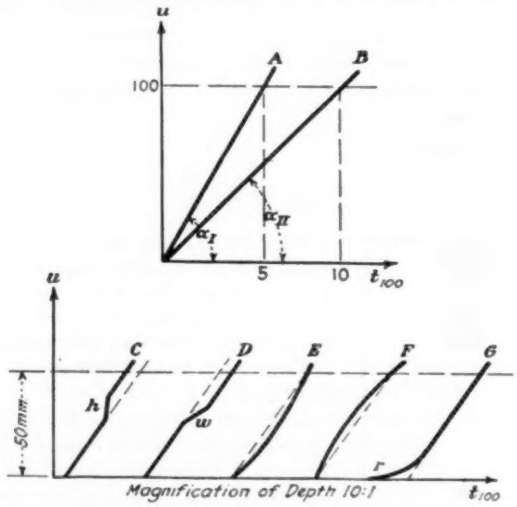

FIG. 4 AUTOGRAPHIC RECORD OF DRILLING-MACHINE TEST

material. Hardness has been defined as the resistance which a body offers to the penetration by another, harder body. Plasticity is the ability of a body to undergo dislocation of its smallest structural particles, as a consequence of the application of external forces, at ordinary temperatures, without disturbance of their coherence. The resistance which a material offers to penetration by a cutting tool is due to its hardness and plasticity; the "machinability" of the material depends upon the combined effect of these two characteristics.

For determining the resistance to penetration by cutting tools, the author devised a drilling testing machine. In this a numerical value for machinability is established by using a drill as a cutting tool and measuring the drilling depth obtained by 100 revolutions of the tool. The test is based upon the consideration that for a definite load the depth of drilling obtained by a definite number of revolutions may be greater in proportion to the better machining qualities of the material under investigation.

The recording pencil automatically draws a diagram the ordinates of which are the number of revolutions of the drill and the abscissas are drilling-depth values. If the material under investigation is homogeneous and its thermal conditions remain constant, the autographic record will be a straight line. The angle α which this line forms with the horizontal (Fig. 4) is a measure of the machinability of the material under test, and material *A* is seen to be twice as difficult to machine as material *B*.

Material *C* shows a hard spot at *h* and material *D* a soft spot at *w*, while material *E* becomes harder toward the inside and material *F* softer. In the curve *G*, the curvature *r* represents the initial attack of the drill, i.e., the vertical travel which must be traversed in every test until both cutting edges of the drill are in effect over their entire length.

The angle of inclination of the straight record line or of the straight

line drawn to connect the starting and end points of the curves represents the value of the machinability of the material. Since, however, the measurement of this angle may introduce an error, the actual depth of the hole drilled by 100 revolutions can be taken as measure of this property (assuming that all external conditions such as load on drill, revolutions, diameter of drill, cutting edges and all angles, remain constant).

The drilling testing machine is described in the original article together with certain investigations carried out by means of it, such as ball penetration and machinability of brass with increasing lead content; influence of silicon content on the machinability of cast iron; influence of speed of cooling on machinability and ball-penetration hardness of cast iron.

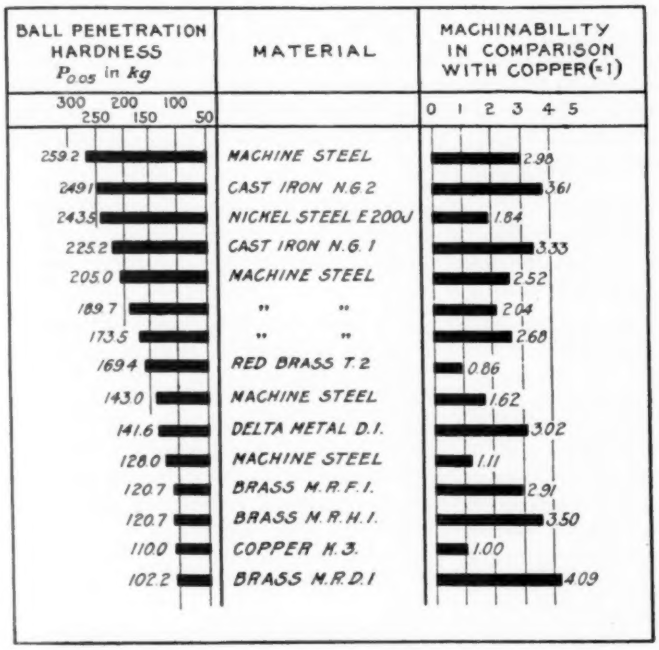

Fig. 5 Ball-Penetration Hardness (Martens-Heyn Units) and Machinability of Various Metals and Alloys

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Test Code for Solid Fuels

Preliminary Draft of a Code in the Series of Nineteen Being Formulated by the A.S.M.E. Committee on Power Test Codes

THE MAIN COMMITTEE on Power Test Codes takes pleasure in presenting this Code for criticism and comment. It is the latest to reach this stage in the approved procedure.

In 1918 the Committee on Power Test Codes was organized by the Council of The American Society of Mechanical Engineers to revise and enlarge the Power Test Codes of the Society published in 1915. The committee consists of a Main Committee of twenty-five members under the chairmanship of Fred R. Low, and nineteen individual committees of specialists who are drafting test codes for the various prime movers and the other auxiliary apparatus which constitutes power-plant equipment.

The individual committee which developed the Test Code for Solid Fuels consists of W. J. Wohlenberg, Chairman, L. P. Breckenridge, E. G. Bailey, B. L. Boye, H. W. Brooks, S. B. Flagg, D. M. Myers, S. W. Parr, G. S. Pope, C. R. Richards, F. M. Rogers, N. Stahl, and E. N. Trump. This Individual Committee, the Main Committee and the Society will welcome suggestions for corrections or additions to this draft of its code from those who are specially interested in the production and use of solid fuels. These comments should be addressed to the Chairman of the Committee in care of the American Society of Mechanical Engineers, 29 West 39th Street, New York, N. Y.

Introduction

1 The Test Code for Solid Fuels is intended to cover all important fuels which are in use for the production of steam for power, heat, and other industrial and domestic uses.

Objects

2 The objects of testing solid fuels may be any one or more of the following:

(*a*) A determination of the composition of the fuel
(*b*) A determination of the heating value of the fuel
(*c*) A determination of the size of the fuel (solid fuels)
(*d*) Classification of fuel
(*e*) A determination of the character of the combustion by an analysis of the products of combustion
(*f*) Smoke determinations
(*g*) A determination of the composition of the ash
(*h*) A determination of the fusing point of the ash.

3 Under the term "Solid Fuels" are included the lignites, bituminous coals, anthracite coals, and coke.

Collecting the Sample

4 (*a*) For a standard test the fuel sample shall be collected and prepared, except as modified herein, in accordance with the method worked out jointly by the American Chemical Society, the American Society for Testing Materials and other materials-testing societies and described in A.S.T.M. Specification D21–16, entitled "Standard Method for Sampling of Coal" which the committee plans to reproduce as part of this Code.

(*b*) As an alternative method for cases in which less accurate results are permissible, a smaller total weight of fuel sample may be collected, it being of course understood that the probable error in sampling varies inversely with the weight of the sample collected. If not otherwise agreed to, solid feul samples shall be collected and prepared in accordance with the rules set forth in A.S.T.M. Specification D21–16. This specification with the modification reproduced below is to be considered as a part of the A.S.M.E. Power Test Code on Solid Fuels and will be reproduced here when this code is published in the final form.

For Par. 5c, page 5, A.S.T.M. D21–16, substitute the following:
The laboratory sample shall be immediately divided into two parts placed in suitable containers, and sealed in such a manner as to preclude tampering. One of these shall be sent to the laboratory for analysis, and the other retained at the plant until satisfactory analysis of the laboratory sample has been completed and reported.

Fuel Sizing

5 In determining the fuel size (for bituminous coal) the gross samples collected as explained in D21–21 Par. 4 (*a*) and 4 (*b*), or an equivalent sample collected in a similar manner and at least equal in weight to the sample referred to above, will be used. Such samples before they have been broken up will be passed over and through the standard screens such as are more completely described in Par.— of the Code on Instruments and Apparatus, and in Bulletin No. 101, Engineering Experiment Station, University of Illinois, and the percentage by weight remaining over each screen will be determined.

The first screen in the series shall be large enough so that not more than 5 per cent by weight of total sample will remain on the screen. The last screen size (smallest opening) in the scale will be such that not more than 20 per cent weight of the total sample will pass through the screen.

Over	5 inches	5 per cent
On $2^1/_2$ inches through	5 inches	10 per cent
On $1^1/_4$ inches through	$2^1/_2$ inches	40 per cent
On $^5/_8$ inch through	$1^1/_4$ inches	30 per cent
Remainder		15 per cent

In designating the size of anthracite fuel used for test purposes (particularly for power boilers using steam sizes of anthracite) the use of trade names should be discouraged. Where, however, it is desired to refer to fuel by trade-size designation, the size of the perforations in the screens through and over which the coal must pass should be definitely stated. Furthermore, limits should be set to the permissible percentages of coal as shown by the sample that will not go through the larger-size screen and that will go through the smaller-size screen. The foregoing is of importance when the size of coal is to be specified in advance of the conduct of the test and particularly where guarantees are to be made when using a certain size of coal.

In determining the fuel size (for anthracite samples) where no trade size is designated the gross samples collected as explained in D21–16 Par. 4 (*a*) and (*b*), or an equivalent sample collected in a similar manner and at least equal in weight to the sample referred to above, will be used. Such samples before they have been broken up will be passed over and through screens having the following sizes of round-hole perforations. Screen No. 1, $4^1/_2$ inches; No. 2, $3^1/_4$ inches; No. 3, $2^3/_8$ inches; No. 4, $1^5/_8$ inches; No. 5, $^7/_8$ inch; No. 6, $^9/_{16}$ inch; No. 7, $^5/_{16}$ inch; No. 8, $^3/_{16}$ inch.

In the process of shaking the fuel through the screens care shall be taken to prevent breaking up the coal. The shaking process must, however, be continued a sufficient length of time so that a complete separation results.

Laboratory Sampling and Analysis

6 The total moisture shall be determined in accordance with rules laid down on pages 5 to 7 of the A.S.T.M. Specification known as Standard Methods for Laboratory Sampling and Analysis of Coal, D22–21.

7 (*a*) In calorific determinations the high heating value shall be used for solid fuels. This shall be stated in terms of standard B.t.u. per pound of fuel on "as received" or "as used" basis.

(*b*) The proximate analysis shall contain the percentages by

Example

	As received, per cent	Dry basis,[1] per cent
Moisture	3.50	....
Carbon	76.80	79.58
Hydrogen	4.45	4.62
Oxygen	4.00	4.14
Nitrogen	1.40	1.45
Sulphur	1.65	1.71
Ash	8.20	8.50
	100.00	100.00

[1] In Bureau of Mines Reports one statement of ultimate analysis is given on dry basis.

weight of the following constituents and shall likewise be stated on the "as received" or "as used" basis: Moisture, Volatile matter, Fixed Carbon, and Ash.

(*c*) The ultimate analysis shall contain the percentages by weight of the following constituents which shall be reported on the "as received" or "as used" basis with moisture and ash content expressed as separate items.

(*d*) A second column to give analysis on dry basis.

8 The proximate and ultimate analyses and the heating value shall be determined under the direction of a competent chemist engaged in fuel-testing work and shall be carried out in accordance with the methods described in the A.S.T.M. specification D22–21 referred to above. This specification with the modifications listed below is to be considered as a part of this A.S.M.E. Power Test Code on Solid Fuels.

Page 2. After last paragraph, add the following:

Coke sample shall be treated as coal samples, but iron or steel grinding mills must be used. Following the grinding process, the ground sample shall be run under a magnet to separate out iron which results from the abrasive action of the coke.

Page 5. Following Par. 7, insert the following concerning Coke Sampling:

In collecting and reducing coke samples all instruments used for crushing shall be made of iron or steel, so that in later preparation of sample in laboratory, particles mixed with the coke sample, due to its abrasive action on crushing instruments, may be separated out by running the ground sample under a magnet.

Page 23. Substitute following for the paragraph starting "Combustion Bombs:"

Only the oxygen bomb calorimeter, such as the Mahler, Atwater, Emerson and Parr's Illium-Alloy Oxygen Bomb, shall be considered as standard in determining the heating value of fuels. Only calorimeter bombs which are non-corrosive or have a non-corrosive lining of platinum, gold, porcelain or other metals not attacked by nitric and sulphuric acids or other products of combustion, may be used.

Classification of Solid Fuels

9 Any of the commercially adaptable systems of classifying solid fuels give only very limited information concerning its behavior characteristics. In other words, a knowledge of the class to which a fuel belongs can be used in only the most general way in determining where and how it shall be burned and what results may be expected.

For such purposes the classifications based on volatile and moisture are just as good as those requiring an ultimate analysis for proper classification. With this in view the "Frazer Classification" given in Appendix A may be used.

Flue Gas

10 (*a*) *Sampling.* The standard flue-gas sampler shall consist of an open-ended iron exploring tube, and the open end of this tube shall be placed at the position in which the gas velocity attains the arithmetical mean of velocities across the section. A determination of this position will require preliminary exploration and judgment. Pockets back of dampers and at bends shall be avoided.

(*b*) *Temperature.* The thermometer bulb or hot junction or other device used for temperature measurements shall be placed as near the open end of the sampling tube as possible and in such a position that the stream flow impinges freely on the temperature-responsive element.

The thermometer or hot junction must be protected from radiation to colder or hotter surfaces which may be in the vicinity, by providing metal, asbestos, or other shields so placed in the gas stream that no direct radiation can take place between the bulb or hot junction and the hot or cold surfaces.

11 *Collecting Flue-Gas Sample.* The gas sample shall be carried from the open-ended pipe in a single tube to the aspirator. The aspirating process shall be strong and continuous. It is preferable to have the flue-gas sample drawn directly into the Orsat apparatus. When this is not feasible, the gas sample shall be collected at the aspirator in standard collecting bottles such as shown in Fig. 1 or in a tube of tin such as illustrated by Fig. 2. For more complete description see Pars. — to — in the Code on Instruments and Apparatus. The gas samples may be collected in quantities proportioned to the rate of burning fuel, or they may be collected in equal quantities at equal intervals of time. In the latter case the average analysis of the gases must be arrived at by weighting the separated determinations proportionally to the weights of fuel burned during the times of collecting the samples from which the analyses are made. Whenever possible the analysis shall be made immediately after collection of the sample.

12 *Flue-Gas Analysis.* The gas samples collected in the manner described above shall be analyzed for CO_2, CO, and O_2 by means of an Orsat apparatus such as is described in Par. — of the Code on Instruments and Apparatus. When more than 0.5 per cent of CO is present the carbon monoxide shall be removed with two cuprous chloride pipes in the Orsat apparatus. If hydrogen is present in the products, an apparatus such as the Mercury, Orsat, Hempel

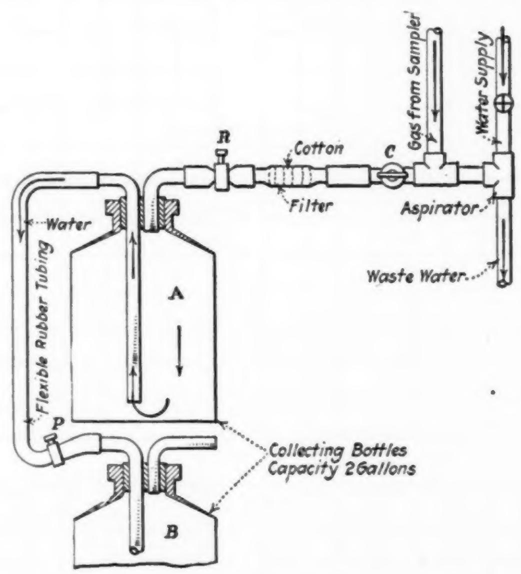

Fig. 1 Apparatus for Collecting and Storing Gas Samples

Fig. 2[1] Sheet-Metal Container for Collecting Gas Samples

or other suitable apparatus described in Par. — of the Code on Instruments and Apparatus should be used.

Smoke Determinations

13 *Qualitative Tests.* In determining smoke density the Ringelmann charts, with lines ruled and spaced as shown by Fig. 3, shall be used, although the overall dimensions of the charts used shall be much greater. These charts and their uses are more fully described in Pars. — to — of the Code on Instruments and Apparatus. In taking observations the Ringelmann charts should be placed in a horizontal row, 50 ft. from the observer and in a line between him and the chimney. The observer glances rapidly from the chimney to the cards and judges which one corresponds with the color density of the smoke.

Readings should be taken every minute, or more often if the variations of smoke density are so rapid as to cause a change of one-half in the smoke-density number on this scale. Careful note should be made of the sky or other background against which the observations are made, as these conditions affect the apparent color of the smoke.

14 Readings should be recorded according to the following scale of values:

[1] **Note:** When the gas is at a pressure below normal it may be drawn in by an aspirator. When, however, it is under pressure above normal it will readily displace the water in the container.

Card	Smoke Density	Description
No. 5 (black)...............	100 per cent	Dense black
No. 4.......................	80 per cent	Medium black
No 3........................	60 per cent	Dense gray
No. 2.......................	40 per cent	Medium gray
No. 1.......................	20 per cent	Light gray
Between No. 0 and 1	Trace	Trace
No. 0 (white)...............	0 per cent	Clear

15 It is to be noted that the above rules apply as stated to smoke in which the particles are black In some cases, however, the smoke may be inherently of some other color, as, for instance, some shade of brown. For such cases the same charts and method shall be used. The observer will now grade the smoke by number according to its density in terms of the base co!or other than black, whatever it is. For instance, if the color be brown, a smoke of 100 per cent brown smoke shall be recorded as Card No. 5, etc.

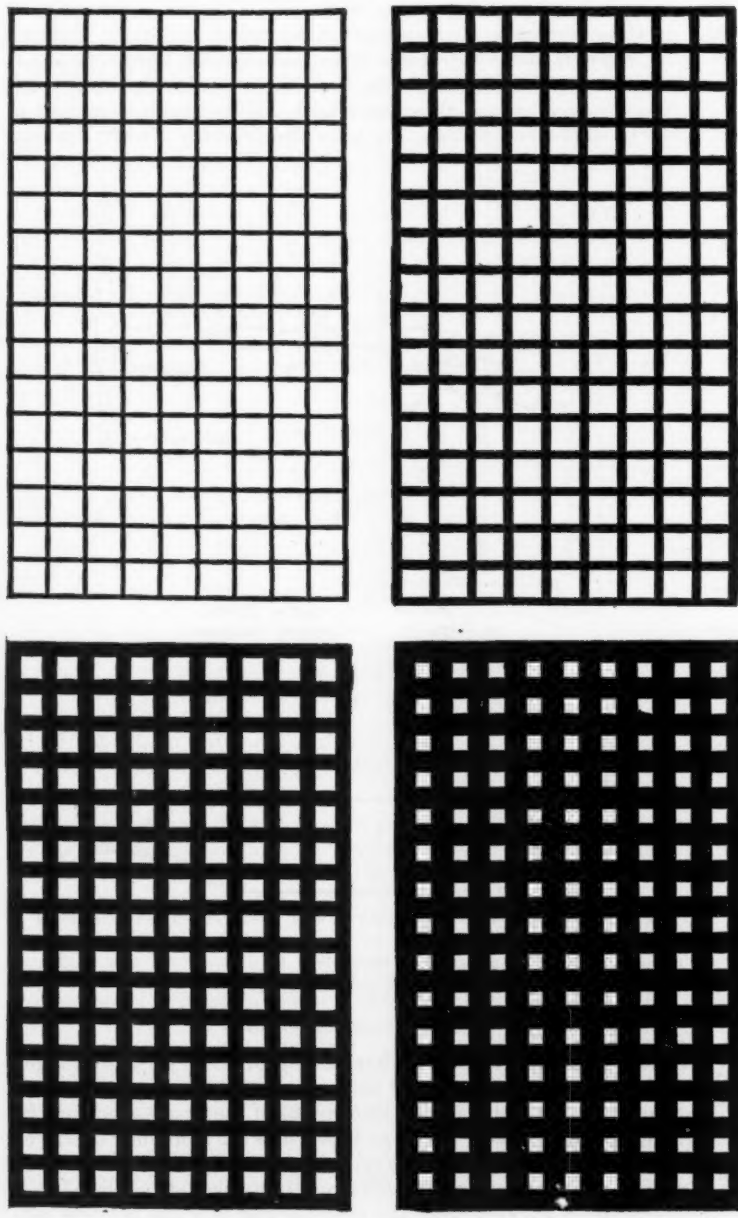

Fig. 3 Ringelmann Smoke Chart

16 *Quantitative Tests.* Methods for the quantitative determination of the solid particles in the flue gases are referred to in Appendix B.

Ash

17 *Sampling Ash.* Immediately after removal of ash from the ashpit, quench with water to stop the burning of any combustible carried over. The method of collecting gross samples for combustible and the moisture determination will depend upon whether or not the total ash can be crushed.

18 *Standard Method of Collecting Gross Sample.* If the total ash can be crushed down to maximum pieces not over $^3/_4$ in. diameter, then the gross sample shall be collected in increments having a proportion of about 50 lb. for each ton of ash weighed out, unless the total gross sample collected in this manner weighs less than 1000 lb. In the latter case the increments shall be large enough to result in a gross sample weighing at least 1000 lb. In cases where the total weight of ash is less than 1000 lb., the total ash will be treated as the gross sample. The increments or samples taken as above directed shall be collected in galvanized-iron cans provided with tightly fitting covers to prevent evaporation of moisture from the sample. The cover shall of course only be removed to add the successive increments.

19 *Alternate Method of Collecting Gross Sample.* If it is not feasible to crush the fine refuse and clinker in one operation, pass the total through a 2-in.-mesh wire screen to separate the clinker from the finer material. If any unburned combustible remains over the screen, separate by hand picking, crush, and throw in with the fine ash. Both clinker material and the screened ash and combustible must be weighed and the weight so found will be known as *"weight of wet clinker from ashpit"* and *"weight of wet ash plus combustible from ashpit."*

The separated clinker shall now be broken up, crushed, and thoroughly mixed. The wet ash plus combustible shall likewise be thoroughly mixed.

To obtain the gross sample of the refuse, mix the crushed clinker and ash plus combustible in proportion by weight to the ratio between "weight of wet clinker from ashpit" and "weight of wet ash plus combustible from ashpit." The weight increments in the mixing process for the gross sample shall be taken according to the foregoing proportions, that is, 50 lb. per ton of screened ash, unless the total sample so collected is less than 1000 lb., in which case the increments shall be so proportioned that the gross sample is at least equal to 1000 lb.; and in cases where the total weight of screened ash is less than 1000 lb. the total ash so collected will be treated as the gross sample. The increments taken as above directed shall be collected in galvanized-iron cans provided with tightly fitting covers.

20 *Laboratory Sample for Determination of Combustible.* (*a*) When Gross Sample Has Been Collected by Standard Method. The gross sample so collected shall be systematically crushed, mixed and reduced in quantity according to Table 1 of A.S.T.M. specification D21-16.

(*b*) When Gross Sample Has Been Collected According to Alternate Method. For this case the gross sample of ash and combustible which has been collected from the screened portion shall be systematically crushed, mixed and reduced in quantity according to Table 1 of A.S.T.M. specification D21-16.

21 *Moisture Sample.* The moisture sample shall be taken from the collected gross sample before the latter has been crushed for subdivision in preparation for the laboratory sample. A grab sample of from 10 to 20 lb. will serve as the moisture sample. Before taking this mix the gross sample by turning over several times with a shovel.

In taking this sample the least possible time should be used, in order to reduce the moisture loss by evaporation to a minimum. This moisture sample shall then be conveyed in a sealed container to the laboratory or place in which the moisture determination is to be made.

22 *Moisture Determination.* The ash sample as received from the test shall be quickly crushed down in a jaw crusher to pass through a 4-mesh sieve. It shall now be reduced to approximately a 5-lb. sample, weighed quickly, spread over galvanized-iron pans such as are described for air drying in A.S.T.M. specification D22-21. These pans containing the sample shall now be placed in an air-drying oven such as shown in Fig. 1 of this specification, and shall have air passed over them at a temperature not exceeding 200 deg. fahr. The process shall be continued until the weight loss is not more than 0.1 per cent per hour.

23 *Determination of Combustible Matter.* (*a*) Combustible in refuse shall be computed by means of difference in weight of total coal, computed weight of total dry ash from the ultimate analysis, and weight of boiler refuse. The heating value of the combustible to be taken as that of pure carbon.

(*b*) For determination of the combustible in fuel siftings through the grate the sifting sample shall be treated according to the method described under proximate analyses in A.S.T.M. Specification D 22–21 for the determination of ash in coal. The heating value of the combustible in the siftings shall be determined by the calorimetric method. For instruments and apparatus involved see Pars. — of Code on Instruments and Apparatus.

24 *Test for Fusing Point of Ash.* At the time of writing this code there is no generally recognized method of testing for the fusibility of ash or of properly interpreting the results arrived at, as the fusing temperature varies considerably under different conditions and for the same apparent fusing temperatures different results are obtained under different operating conditions. However, the method referred to in Appendix C for a determination of the fusing temperature has been tentatively adopted by A.S.T.M. under serial designation D22–21, and has been found to give reasonably consistent results if carefully carried out according to the directions stated. It is therefore recommended for use in such determinations.

LOCOMOTIVES

25 *Gross Sample from Pan.* Collect the gross ash sample from the pan as outlined in Pars. 18 or 19, being careful to prevent loss of ashes.

26 *Stack Sample of Cinders.* For an accurate determination of the cinder content in gases exhausting from locomotive stacks, all known methods which may lead to accuracy under actual running conditions are impracticable. It is therefore necessary to make these determinations in locomotive-testing plants such as those of the Pennsylvania Railroad at Altoona, Pa., and of the Departments of Railroad Engineering of the Universities of Illinois and Purdue.

27 *Laboratory Sample for Determination of Combustible in Solids.* By quartering and reducing according to the approved method a sample of from 2 to 4 lb. may be taken from the gross sample. This should be placed in a tightly sealed jar for delivery to the laboratory.

28 *Analysis of Solid Samples.* The cinder sample shall be analyzed for combustible according to the method outlined in Par. 23.

POWDERED COAL

29 *Gross Ash Sample from Furnace.* This shall be collected and weighed at convenient intervals, care being taken that none of the fine ash deposit is lost. If there are large slag formations, these should be broken down and weighed separately.

30 *Gross Ash Sample from Stack.* In collecting this sample the rules outlined in Appendix B may be used.

31 *Preparing Laboratory Samples.* Laboratory samples from both the gross stack-ash sample and the gross furnace-ash sample shall be prepared from said gross samples by the standard process of reducing, accompanied by quartering and mixing. The laboratory samples shall weigh from 2 to 5 lb. Separate samples shall be taken for the furnace and stack. If the slag is to be analyzed the sample shall be prepared by crushing all of the slag so that it will pass through a $^3/_{16}$-in. screen. The laboratory sample shall be prepared from the total crushed slag by a reducing process, accompanied by quartering and mixing according to the standard method.

32 *Analyzing Laboratory Samples.* The laboratory samples above prepared shall be analyzed for combustible according to the standard method.

COÖPERATION FROM THE BUREAU OF MINES

33 In cases of important acceptance tests, exportation of coal, etc., it is often imperative to have the analysis performed by such an organization as the Government laboratories afford. The conditions under which the Bureau of Mines will analyze and test coal are stated in Appendix D.

LIST OF INSTRUMENTS AND APPARATUS REQUIRED FOR THE TESTING OF COALS

Collecting the Sample and Moisture Determination
- Galvanized-iron cans with tightly fitting covers, approximately 18 in. diam. by 30 in. high
- Shovel
- Tamper
- Heavy Duck or Canvas (6 ft. by 8 ft.)
- Broom
- Rake

Fuel Sizing
- Standard screens of punched plate having round holes, screen ratio = 2.

Laboratory Sampling. Analysis

Calorimetric Determinations
- Oxygen bomb calorimeters, such as Atwater, Emerson, Mahler and Parr's Illium-Alloy Oxygen Bomb. Only calorimeter bombs which are non-corrosive or have a non-corrosive lining of platinum, gold, porcelain or other metals not attacked by nitric and sulphuric acids may be used.

Flue-Gas Sampling
- Sampling spiders or tubes
- Aspirators
- Sampling bottles
- Water-jacketed tubes

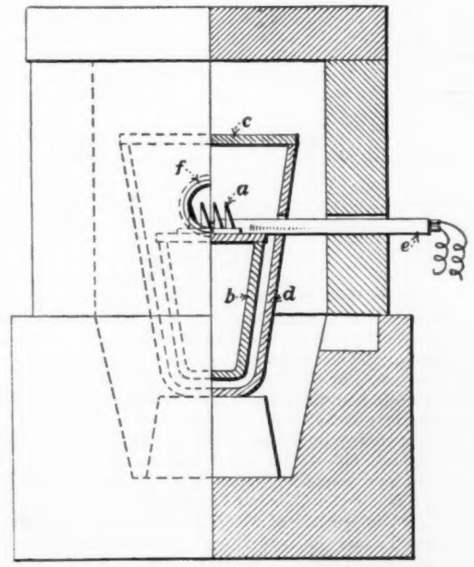

FIG. 4[1] ELEVATION AND SECTION OF NO. 3 MELTER'S FURNACE ARRANGED FOR FUSION TESTS

Flue-Gas Temperature
- Thermometers
- Electric or expansion pyrometers properly calibrated, optical pyrometer of Leed & Northrup or Wanner type, also Holborn-Kurlbaum pyrometer.
- Shields to prevent radiation errors.

Flue-Gas Analysis
- Orsat apparatus
- Hempel or similar gas-analysis apparatus.

Smoke Determinations
- Qualitative
  - Ringelmann Smoke Charts
- Quantitative
  - See Appendix B of Code.

Sampling Ash
- Galvanized-iron cans with tightly fitting covers
- 2-in.-mesh wire screen
- Shovel, blanket (6 ft. by 8 ft.)
- Broom, rake
- Crusher

Laboratory Sample. Moisture and Combustible Determinations of Ash

Testing for Fusing Point of Ash
- Muffle furnace
- Pot furnace (such as No. 3 Melter's of American Gas Furnace Co., also Modified No. 29 Meker Furnace). See Fig. 4
- 60-mesh screen
- Fire-clay roasting dish
- Agate mortar or agate-mortar grinder
- Silica or porcelain capsule
- Steel spatula, $^5/_8$ in. deep by $1^3/_4$ in. diam.
- Brass mold. See Fig. 5

Hot-plate, sheet-iron plate
Platinum and platinum-rhodium thermocouples with high-resistance millivoltmeters or Northrup pyrovolter
Various crucibles, etc.
See Appendix C of this Code

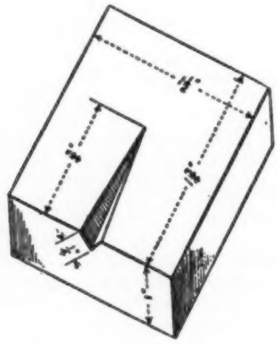

Fig. 5[1] Cone Mold

APPENDIX A

Frazer Classification for Coal

Anthracites		Volatile below 5 per cent
Semi-anthracites		Volatile 5–10 per cent
Semi-bituminous		Volatile 15–22 per cent
Bituminous	Eastern	Volatile 25–35 per cent Vein moist. 2–4 per cent
	Mid-Continental	Volatile 35–45 per cent
Black lignites or sub-bituminous		Volatile 35–40 per cent Vein moist. 17–20 per cent
Brown lignites		Volatile 25–45 per cent Vein moist. 20–25 per cent

APPENDIX B

Quantitative Test for Solids in Flue Gases

For the determination of solids such as cinders, an efficient cinder catcher through which the total gases are passed will lead to more accurate results than any sampling device which takes only a very small fraction of the total gases. Furthermore, due to the relatively slow movement of the gases in many natural-draft installations, it is impossible to obtain a representative sample by simple means through a small sampling tube. (There is insufficient kinetic energy in the particles to carry them through such tubes.) It is often impracticable to have the total gases passed through a cinder catcher, and for such cases no generally recognized method is in use The methods used (a) by the Chicago Department of Smoke Inspection[1] and (b) those reported in Bureau of Mines Bulletin 223, entitled An Investigation of Powdered Coal as Fuel for Power Plant Boilers, by Kreisinger, Blizard, Augustine and Goss, have been used with success.

The latter method is particularly to be recommended when it is desired to obtain in addition to the cinder content also a measurement of the fine dust such as may be present in gases escaping from powdered-coal furnaces. A description of the apparatus and its use will be found in Pars. — to — of the Code on Instruments and Apparatus.

APPENDIX C

Fusion Test of Ash

For the standard fusion test of ash, see Method of Test for Fusibility of Coal Ash, A.S.T.M. Specification having the serial designation D22–21.

APPENDIX D

Fuel Testing and Analysis by Bureau of Mines

In the Bureau's Schedule 3-A, the fees for analyzing coal are announced, and the conditions under which analyses and tests will be made are stated as follows:

"The conditions under which the Bureau of Mines will, for a fee, analyze samples of coal and determine the softening temperature of coal ash are set forth below.

"(1) Application for the making of such analyses and tests must be made to the Director of the Bureau of Mines, Washington, D. C.

"(2) The Bureau of Mines cannot undertake to make analyses of coals for private parties except in cases where good reason exists why such analyses should be made in a Government laboratory, as in cases where the coals are to be exported for sale in other countries, or in cases involving arbitration, etc.

"(3) In order that the analyses and tests made by the Bureau may be fairly representative of the coal to be analyzed, it is essential that the samples of such coal be collected and shipped in the manner approved by the Bureau of Mines.[1] (See method described in Technical Paper 1, The Sampling of Coal in the Mine, and Bulletin 116, Sampling Coal Deliveries, and Types of Government Specifications for the Purchase of Coal.)

"With each sample of coal should be furnished the name of the coal bed and of the mine from which the sample came. The location of the mine with respect to the State, county, and the shipping point or nearest town should also be given."

[1] Note: Figs. 4 and 5 are reproduced from Bulletin No. 129 (1917) of the U. S. Bureau of Mines, entitled The Fusibility of Coal Ash and Determination of the Softening Temperature, by A. C. Fieldner, A. E. Hall and A. L. Field.

[2] See report of 1915 of Chicago Association of Commerce Committee of Investigation on Smoke Abatement and Electrification of Railway Terminals, pages 150–151.

[1] Conditions here referred to for sampling are practically identical to those specified by this code as the Standard Method.

Device for Test of Einstein Theory

THERE is now being built near Chicago, Ill., an enormous apparatus which looks like a gigantic letter O in block type, with one side heavily shaded, to authenticate or discredit the theory of relativity. The University of Chicago is behind this monumental experiment costing hundreds of thousands of dollars, and Prof. Albert A. Michelson, among whose achievements is included the measuring of the star Betelgeuse, is in charge of it. Associated with him is H. G. Gale.

Eventually there will be completed a rectangle of 12-in. pipe, 1800 ft. long and 1200 ft. wide. A double length of pipe will form one side, thus providing for a check on the results. In this apparatus there is used 72,000 ft. of 12-in. water main and 14,000 lb. of lead to make the joints airtight.

In a portable garage, within which one corner of the rectangle will lie, there will be set up an arc light, which is to throw through the pipes within a closed circuit two beams of light, traveling in opposite directions and caught and passed along by mirrors at each corner.

The object of the experiment is to determine whether or not the two beams of light, traveling in opposite directions around the rectangle, require exactly the same time to complete the circuit. The system of mirrors at the four corners of the rectangle constitutes an interferometer—which is one of the most celebrated inventions of Professor Michelson—and will make it possible to compare the time required for the two beams of light to make the circuit.

The comparison will be brought down to within a fraction of the time required for light to make a single vibration. This time is exceedingly minute. The unit of time used in the experiment will be about 2,000,000 times 900,000 times 256 times smaller than the second.

An observer recording the play of light on the mirrors will be able to detect the slightest variation in the velocity of the beams through the longer and the shorter legs of the rectangle. If no difference in the time of the rival beams is perceived it will be apparent that light is not affected by the earth's rotation; or in other words that the ether rotates with the earth.

It is at this point that the actual bearing of the experiment on the Einstein theory of relativity enters, for according to that theory, one beam should travel around the circuit in slightly less time than the other. Generally speaking, proof that the ether rotates with the earth will be considered as contradicting the Einstein theory. (*New York Evening Post*, August 2, 1924.)

Recent issues of *Le Bois* and *Bois et Resineux*, leading French lumber journals, contain descriptions of the demonstration of the Imbert "gazogene," which recently took place in the Berliet factory at Lyons before representatives of the Ministry of War and of the press.

The machine used in the experiment was a Berliet automobile of 25 hp. The Imbert "gazogene" according to these descriptions creates carbon monoxide by the contact of air with the incandescent charcoal; the gas is mixed with air and introduced into the motor cylinders, and the remainder of the process is similar to that in a gasoline motor. The engine can be started in a few moments after the charcoal is fired. The gazogene weighs 50 kg. (110 lb.) and consumes 15 kg. (33 lb.) per 100 km. (62.14 miles). Its heater and purifier, with charcoal sufficient for 200 km., are behind the vehicle.

The expense of running a 25-hp. motor vehicle by gasoline is from 36 to 40 francs per 100 km.; by the use of charcoal it is claimed that this cost can be reduced to 5 or 6 francs.—*Power*, July 25, 1924, p. 193.

Correspondence

CONTRIBUTIONS to the Correspondence Department of Mechanical Engineering are solicited. Contributions particularly welcomed are discussions of papers published in this journal, brief articles of current interest to mechanical engineers, or comments from members of The American Society of Mechanical Engineers on activities or policies of the Society in Research and Standardization.

The Elasticity of Pipe Bends

To the Editor:

The paper entitled the Elasticity of Pipe Bends, by Messrs. Crocker and Sanford, published in Mechanical Engineering, March, 1923, gives an entirely new and comprehensible method for their calculation. Nevertheless, in attempting to apply it, the writer has met with some difficulties and would therefore request further information covering the following points:

1 The method of constructing the diagrams of Figs. 7, 8 and 9, and especially the dependence between the angles of inclination of the lines (guide and radial) diverging fan-like from the lower right- and left-hand corners of the diagrams.

2 The method of using the diagrams. For instance, referring to Fig. 7, in finding the stress for a 12-in. expansion U-bend it is not clear why, from the perpendicular line for an 8-in. bend considered as base line, a dash line is drawn parallel to the nearest guide line. Further, in the example given for the use of the diagram shown in Fig. 8 for a 16-in. pipe, the method of using the diagram is not entirely clear to the writer. Therefore he would ask that other examples be given of the use of each of the three diagrams, together with details of the steps taken in their solution.

Moscow, Russia. D. Tocareff.[1]

[Mr. Tocareff's letter was submitted to the authors of the paper in question and the following reply has been received from Mr. Crocker.—Editor.]

[1] Engineer of 1st State Electric Station, Raushkaja Quai.

To the Editor:

In reply to the request made by Mr. Tocareff, we are glad to furnish the following information:

In general, the construction of the diagrams of Figs. 7–9 is as follows: Fig. 7 is a graphical solution of Equation [11] of the complete paper (not published in the abridged article in Mechanical Engineering) for 8-in. double-offset expansion U-bends having various radii of curvature. The diverging lines $R = 10$ in. to $R = 120$ in. have slopes, depending on the relation between expansion and bending stress. Since the equation for the double-offset expansion U-bend is identical with those for the expansion U-bend, the simple U-bend, and the quarter bend except for the constant involved, scales of maximum bending stress for these other bends were placed on this diagram so that one diagram serves all four shapes.

Figs. 8 and 9 are graphical solutions of Equation [10] of the complete paper for 16-in. double-offset expansion U-bends having various radii of curvature. The diverging lines $R = 20$ in. to $R = 120$ in. have slopes depending on the relation between expansion and force. Scales of force for the other shapes of bends were placed on the diagram so that each diagram applies to all four shapes.

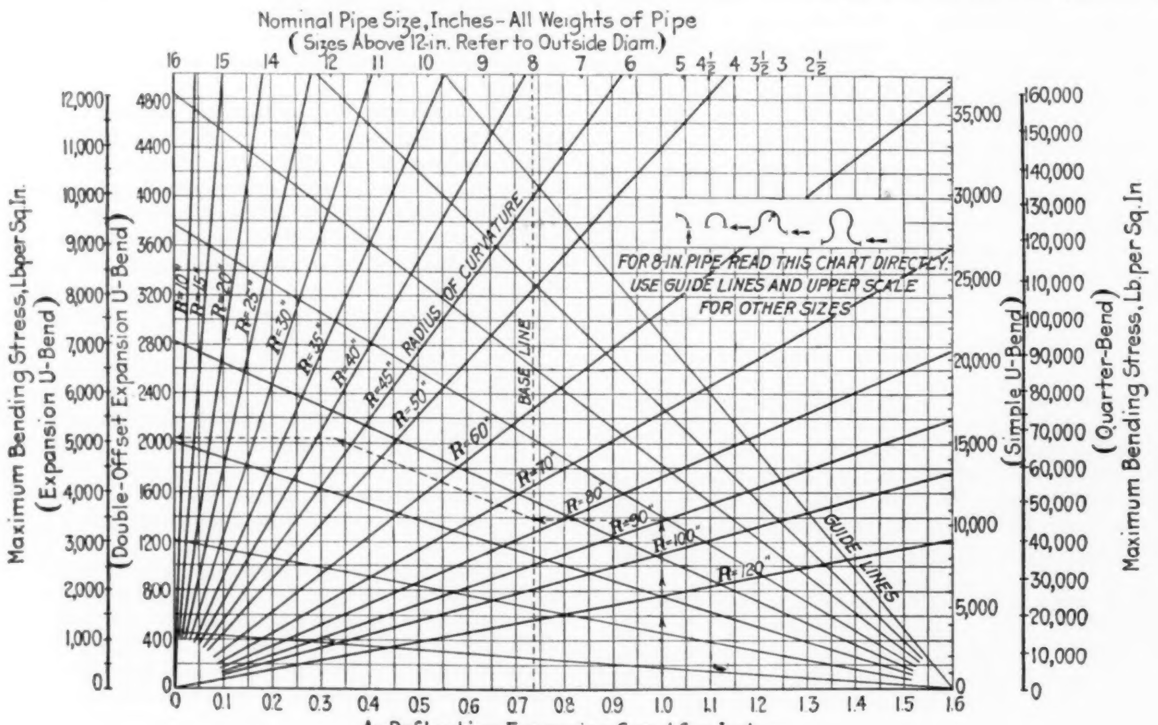

Fig. 7 Stress vs. Displacement for Various Shapes and Sizes of Pipe Bends

In each case the scale of pipe sizes at the top has its origin at the right boundary line of the diagram. In Fig. 7, the scale of pipe sizes was laid off according to the outside diameter of the pipe, the smallest scale division being $^1/_2$ in. In Figs. 8 and 9, the scale of pipe sizes was laid off according to the moment of inertia of the pipe sections. The position of the various commercial sizes of pipe is indicated on these scales for convenience.

The guide lines radiating from the lower right-hand corners of the diagrams might be omitted entirely without affecting the use of the diagrams. They are drawn in at random and serve only to indicate the procedure when the diagram is used for a pipe size other than that for which it was constructed. It is to be noted that in going from the base line to the desired pipe size, the dash line is drawn radially from the lower right-hand corner and *not* parallel to the nearest guide line.

We have assumed the neutral axis of the pipe as passing through the center of the section. The maximum bending stress depends upon the distance between the neutral axis and the extreme fiber, which in this case is the outer radius of the pipe. The maximum bending stress in any size of pipe, then, is proportional to the radius or the outside diameter of the pipe. Thus in Fig. 7, the stress for any pipe size is proportional to the actual distance on the upper scale of that size from the right of the diagram. If the maximum bending stress set up by a given deflection in an 8-in. bend of a given radius is indicated by the vertical distance from the bottom of the diagram to a point on the base line, then a line drawn from the lower right-hand corner, through this point will intersect vertical lines drawn through the other pipe sizes on the upper scale so that the distance from the bottom of the diagram to this radial line indicates the maximum bending stresses set up in bends of other than 8-in. pipe, the deflection on the radius of curvature being the same as for the 8-in. bend. In Figs. 8 and 9, the force-deflection relation between bends made up of various sizes of pipe is given in the same way.

Perhaps Mr. Tocareff's trouble can be cleared up by going through in detail the sample problem illustrated in Fig. 7. Given: a 12-in. double offset expansion U-bend bent to a radius of 90 in. and taking up an expansion of 1 in. Required: to know the maximum bending stress in the bend corresponding to these conditions. Starting at $\Delta = 1$ in. on the bottom scale, rise vertically to intersect the line $R = 90$ in., go horizontally to intersect the base line, then diagonally on a line through the lower right corner to intersect the vertical 12-in. pipe-size line (not drawn); then read the stress horizontally across the sheet as 2040 lb. per sq. in. If this had been an 8-in. pipe the problem would have been finished at the time the line $R = 90$ in. was intersected and the stress would then have been read as 1370 lb. per sq. in. However, as the problem concerned 12-in. pipe instead of 8-in. pipe, it was necessary to proceed diagonally from the base line to obtain the stress by proportion.

Sabin Crocker.

Detroit, Mich.

The Hardness of Metals and Hardness Testing

To the Editor:

The article in Mechanical Engineering for June, 1924, on the Hardness of Metals and Hardness Testing has been read with considerable interest. Articles on hardness, however, do not appear to give proper consideration to some of the elements affecting hardness.

The principal reason that an article is hardened is to resist wear, and the value of an article oftentimes depends on its properties of resistance to wear. Therefore this resistance in the last analysis is the proper measure of the value of hardness. It is recognized that wear tests will furnish the most accurate determination as to those properties of steel which enable it to resist wear. Rebound-measuring devices and penetration-measuring systems are valuable to the extent that the readings derived therefrom bear definite relation to resistance to wear.

It can also be stated that articles, mainly those made from steel, are not hardened just for the sake of obtaining some definite hardness on some scale, but, as in the case of steel rails, locomotive tires, crankshafts, gears, bearings, and similar parts, the chief if not the only reason is to obtain resistance to wear.

It can further be stated that the scales of arbitrary numbers on our hardness-indicating systems are out of all proportion to the true measure of hardness; for instance, in a certain case the scleroscope reading of soft steel shows a hardness of 30 and of hardened steel a hardness of 90, yet a tool of the hardened steel will remove by cutting an amount of metal of the soft steel out of all proportion to weight as compared to loss on the hardened steel tool, measured by wear of the tool. Therefore it can be truthfully stated that the steel tool is not only three times as hard as the soft steel but is millions of times harder.

Another example is the loss of weight on a diamond point compared to that of the material removed in truing an emery wheel. The emery wheel will be appreciably reduced in diameter, whereas the loss of weight in the diamond is immeasurable. It is not straining the truth, therefore, to state that the diamond is a million times harder than the emery instead of being only one or two per cent harder as might be indicated on some of our arbitrary hardness measures.

Another example is that we find certain alloys of steel that resist wear in bearings to a greater extent than other alloys which, on arbitrary scales, would seem to be harder. It therefore appears that for all practical engineering use, resistance to wear is the true measure of hardness on engineering parts made from steel.

Canton, Ohio. T. V. Buckwalter.[1]

[The following may be of interest in connection with Mr. Buckwalter's letter on hardness as contributing to an understanding of this property of metals.

It is of course true that in a great majority of cases an article is hardened to resist wear. At the same time it is not always necessary for an article to be hard in order to resist wear and, for example, in the familiar instance of phosphor bronze we have particles of extremely hard copper phosphide distributed through a soft matrix of metallic copper. In this case it would be really difficult to say which of the two constituents, the hard or the soft, contributed most to the wear resistance of the bearing.

Historically, the Moh scale was the first attempt to measure the hardness of minerals. This was, however, purely a means of classifying minerals, bearing no relation whatever to their ability to resist wear.

Taking again the case of bearings, we find that manufacturers specify two hardnesses: for example, in ball-bearing races the Brinell hardness of, say, 160 for the metal to be machined, and the ability of the metal to take a very much higher hardness on final treatment. Now the low hardness, which for its purpose is just as essential as the high hardness, is required not for wear resistance, but exclusively to make the machining of the material commercially possible. In the case of numerous new alloys, such as high-chromium heat-resisting alloys, the "low" hardness, that is, the maximum permissible hardness, is a vital element of specification as the machinability of the casting is measured thereby.

There are numerous other products where hardness means something different from resistance to wear although, as Mr. Buckwalter correctly states, it might be always brought into definite relation to this resistance. Among such products may be mentioned armor plate, the soft noses on armor-plate-piercing projectiles, specification of maximum hardness for copper bands on shells, etc.

As a matter of fact, resistance to wear depends not only on hardness of the bearing material but on a good many other factors, two of which may be mentioned here. The first is the inherent lubricating ability of the material, which explains, for example, why gray iron with the carbon in soft flakes is a better bearing material than malleable iron or steel with the carbon in compound form or distributed in hard globules. Another element is what might be called a temperature coefficient of hardness. It is this that makes an Adamite roll better than an ordinary cast-iron roll and is now leading glass manufacturers to the employment of special and at times extremely expensive alloy rolls for rolling glass.

Mr. Buckwalter's remark that "the scales of arbitrary numbers on our hardness-indicating systems are out of all proportion to the true measure of hardness" is entirely correct, and is one of the reasons why it was suggested in an editorial in last month's Mechanical Engineering that until a definite physical conception of hardness has been established and universally adopted the use of the term hardness should be abandoned, and that we should speak of Brinell numbers, Shore scleroscope numbers, etc., rather than of Brinell hardness, Shore scleroscope hardness, etc. So long as it is clearly realized that the scleroscope numbers are purely arbitrary there is no reason to assume offhand that steel showing a number of 90 is "three times as hard as the steel showing a number 30," just because the arbitrary character of the numbers is emphasized, and the misleading impression that these arbitrary numbers bear a definite relation to the physical character of hardness should be removed.—Editor.]

[1] Chief Engineer, The Timken Roller Bearing Co. Mem. A.S.M.E.

British Engineers Honor President Low

THE Institution of Mechanical Engineers conferred Honorary Membership upon President Fred R. Low of The American Society of Mechanical Engineers during Mr. Low's sojourn in London this summer. This honor is not only a recognition of Mr. Low but a graceful courtesy to the A.S.M.E.

The Summer Meeting of the Institution of Mechanical Engineers was held July 7 to 9 during the World Power Conference, and guests from the United States were heartily welcomed in the informal gathering at the Empire Exhibition which constituted the meeting.

The feature event of the meeting was the dinner on Monday evening, July 7, at which President W. H. Patchell overturned a precedent that demanded a list of long speeches. They were replaced by short talks by the chairman, Fred R. Low, and John R. Freeman, and the rest of the evening was given over to the pleasures of conversation.

A.S.M.E. Boiler Code Committee Work

THE Boiler Code Committee meets monthly for the purpose of considering communications relative to the Boiler Code. Any one desiring information as to the application of the Code is requested to communicate with the Secretary of the Committee, Mr. C. W. Obert, 29 West 39th St., New York, N. Y.

The procedure of the Committee in handling the cases is as follows: All inquiries must be in written form before they are accepted for consideration. Copies are sent by the Secretary of the Committee to all of the members of the Committee. The interpretation, in the form of a reply, is then prepared by the Committee and passed upon at a regular meeting of the Committee. This interpretation is later submitted to the Council of the Society, for approval, after which it is issued to the inquirer and simultaneously published in MECHANICAL ENGINEERING.

Below are given interpretations of the Committee in Cases Nos. 446–453, inclusive, as formulated at the meeting of June 17, 1924, all having been approved by the Council. In accordance with established practice, names of inquirers have been omitted.

Cases Interpreted under the Rules of the 1924 Revised Edition of the Boiler Code

CASE No. 446

(In the hands of the Committee)

CASE No. 447

Inquiry: An interpretation is requested of the application of Par. S-15 in the Specifications for Steel Boiler Plate, which permits an undergage variation of not more than 0.01 but leaves the overgage allowance as a matter of contract between steel manufacturer and boiler builder, to Par. P-253, which prohibits the punching of any part of a rivet or staybolt hole in material more than $^5/_8$ in. in thickness. What is the permissible overgage variation in steel boiler plate when considering Par. P-253?

Reply: It is the opinion of the Committee that where the overgage limits of steel boiler plate are under consideration, the prohibition of punching of rivet or staybolt holes in material $^5/_8$ in. in thickness need not be considered applicable as long as the overgage variation of the plate thickness does not exceed $^5/_8$ in. in thickness by actual measurement at the edge of the plate by more than 6 per cent.

CASE No. 448

Inquiry: Is it permissible, in the construction of water-tube boilers, with tubes inserted in the shells of the drums, to so locate the riveted longitudinal joints of the drums that they are exposed to the products of combustion? Attention is called to the fact that the Boiler Code prohibits the exposure of longitudinal joints of boilers to the fire or products of combustion.

Reply: Attention is called to the fact that the prohibition in the Boiler Construction Code of the exposure of longitudinal joints to the fire or products of combustion which appears in Par. P-189 is applicable solely to horizontal-return tubular boilers. Attention is called to Par. P-193 of the 1924 revised edition of the Boiler Code in which the last sentence stipulates that "when reinforcing plates or butt straps are exposed to flame or gas of the equivalent temperature, the joints shall be protected therefrom."

CASE No. 449

Inquiry: Is it permissible, under the requirements of the Boiler Code, to attach the lower tube sheet of a vertical-tubular boiler to the furnace sheet by lapping and welding the lapped edges on both the fire and water sides of the sheets, provided the welded seam is located between two rows of staybolts to the outer shell of the boiler?

Reply: It is the opinion of the Committee that inasmuch as the expansion and contraction in the vertical tubes may set up a tensile stress in the welded section, Par. P-186 would prohibit the construction.

CASE No. 450

Inquiry: Is it permissible, under the Boiler Code, to use autogenously welded longitudinal and circumferential seams instead of riveted construction in the furnace sheet and in the outside shell plate of an internally fired vertical boiler, provided the furnace is supported by staybolts screwed through the outside shell? The type of boiler is a vertical, cylindrical boiler having an internal furnace the full height of the boiler, which is practically an annular water space, into the inner shell of which are fitted spiral coils attached by threaded and expanded connections to the upper and lower part of the boiler.

Reply: It is the opinion of the Committee that the use of autogenous welding for the outside sheet will not be permissible under the requirement of Par. P-186, and that such construction will be permissible only for boilers constructed to the requirements of the Low-Pressure Heating Boiler Section of the Code. For the inside of furnace sheet, see Case No. 375.

CASE No. 451

Inquiry: Is it permissible, under the requirements of the Boiler Code, in attaching the ends of through stays to the heads of Scotch marine-type boilers to thread the ends of the through rods into heavy plates or blocks that are fastened to the inner suface of the head by rivets? The purpose of this proposed construction is to avoid the large nuts on the projecting ends of the through rods outside of the head where they are very much in the way of the smoke box and furnace front.

Reply: The theory of the formula and constants provided in Par. P-199 is predicated upon the ends of the through rods being secured in some more positive way than by the holding power of the thread in the plate, and inasmuch as no such additional provision is made in the arrangement submitted, the Boiler Code Committee is of the opinion that this form of construction does not meet the requirements of the Code.

CASE No. 452

Inquiry: In the application of Pars. H-51 and H-107 of the Heating Boiler Section of the Code, to water-relief valves, interpretation is requested as to what may be considered the relieving point of the valve. In actual practice with water-relief valves of the diaphragm-operating type, it is found that there is a difference of from 3 to 8 lb. between the pressure at which the valve begins to drip and that at which it opens sufficiently to deliver a stream of water.

Reply: It is the opinion of the Committee that the pressure at which such a water-relief valve begins to drip should be taken as the relieving point.

CASE No. 453

Inquiry: Is it permissible, under the Low-Pressure Heating Boiler Section of the Code, to so locate the water-gage glass on heating boilers fitted with a two-pass arrangement of tubes that the lowest visible part of the glass is on a level with the bottom of the top row of tubes at the front end of the boiler?

Reply: It is the opinion of the Boiler Code Committee that the lowest visible point of the water-gage glass should not, for low-pressure heating boilers, be located at a point lower than that specified for fusible plugs in Par. H-64.

MECHANICAL ENGINEERING

A Monthly Journal Containing a Review of Progress and Attainments in Mechanical Engineering and Related Fields, The Engineering Index (of current engineering literature), together with a Summary of the Activities, Papers and Proceedings of

The American Society of Mechanical Engineers

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The Record of Two Generations of Engineering Achievement

THE forty-five years of mechanical-engineering literature which constitute the newly indexed Transactions of the A.S.M.E. record the developments in engineering of half a century as well as the professional growth of the Society. Surveyed from the viewpoint of the present, the early volumes reveal the achievements of prominent engineers and reflect the practice of their times and their professional interests and controversies. Today's volumes show today's achievements and today's practice, and also many interests and controversies which have not subsided nor been settled.

An examination of volume one, that slender book of which the members in 1881 must have taken such pride and which today holds so much readable matter, shows it to contain papers on problems of engineering research—today one of the most lucrative fields of endeavor and one of the most fruitful sources of contributions; on standards, the necessity for which increases, and a field in which the Society has played an important role; on the metric system, that recurrent shibboleth of scientists and engineers; and the time-honored presidential address on the aims and responsibilities of the engineer.

And there are the contrasts, too. In 1881 papers on details of steam-engine design and operation were of interest to engineers, where today the steam turbine has usurped the field; and it seems that there has been some advance in the value of the theoretical method of analysis when we read, in 1881, what is practically an apology for the study of thermodynamics, and, in 1923, a series of papers dealing with the thermodynamical analysis of power-plant design and operating problems.

One gets a feeling that it was an age of experimentation, of a burning desire to seek out the elusive heat unit and apply the calipers to the vector representative of the invisible but persistently manifested force which turned cranks and had to be reckoned with in design of the tremendous engines which were the mechanical monuments of those days. It was, in short, an inquiring and rational mind, which sought the explanation of the fundamentals involved in the creations of vigorous but sometimes unreasoning hands, that guided the destinies of those early papers.

There were giants in those days. Their names are the household gods of mechanical engineering as we know it today, and their vigor and enthusiasm built up the Society and left posterity with this accumulation of literature which is the Society's greatest visible claim of worthiness to exist.

There we find Thurston, Holley, Coleman Sellers, Denton, Sweet, C. T. Porter, Towne, Stirling, the Webbers, Samuel and Wm. O., Taylor, a name known in all circles, Kent, Peabody, Lanza, Hutton, Ball, Wellman, Gantt, Emery, Fritz, and Melville, to mention but a few. And from Europe such men as Mallet, Dwelshauvers-Dery, Linde, Reuleaux, Rateau, and Bessemer swell the list of contributors. Besides these a host of others, as well known or perhaps better known today, since they are our most active members and finally a coterie of young men with superb mental and educational equipment who are adding bit by bit to the knowledge of the engineer by their researches and to the glory of the engineer by their achievements.

The story of the engineer's awakening to his responsibility in the science of management is told in the appearance of papers in the Transactions. Towne, in 1889, Halsey, in 1890, Taylor, in 1895, and Gantt, in 1901, laid the foundation for what has today become one of the greatest activities of the Society. The paper by Taylor, Shop Management, presented in 1903, is a classic of engineering literature, a forerunner of that other classic by him, On the Art of Cutting Metals. The significance of these papers lies chiefly in the application of scientific methods of analysis to two fundamental problems of industry which have existed since prehistoric times, the man and the tool.

There are other instances which may be found in the Transactions which show the shaping of knowledge through the efforts of the Society and its individual members. To mention but a few: The properties of steam, really a problem for the physical-chemist rather than the engineer, early concerned engineers and designers. Numerous papers mark the progress of knowledge and engineering practice through these forty-five volumes; and we have now assurance of highly scientific and authoritative data as a result of the clamor of these papers. Progress in thermodynamics and power has been mentioned. Another series of researches, bearing fruit from year to year in the Transactions, is the measurement of the flow of air and gases—with which we associate the names of Durley, Thomas, Judd, and numerous others. Heat transmission and the pipe-covering experiments, to which McMillan, Bagley, and Heilman have successively contributed, is another series, early endeavors in which can be seen in Professor Ordway's paper of 1884, and which date back to Péclet.

The description of the Edison steam dynamo by its designers, T. A. Edison and Charles T. Porter, marks (1882) the beginning of an extensive literature in power-plant design, which includes the revolutionary substitution of the steam turbine for the reciprocating engine and alternating for direct current, and which looks forward now to changes perhaps as revolutionary in fundamental cycles and steam pressures and temperatures hinted at in 1896 by Professor Thurston. This latest development has made of a steam engineer a metallurgist and metallographer, and has introduced him to materials unknown to the founders of the Society and to properties of materials unsuspected by them.

The technology of testing, the foundation of our knowledge of facts, the support of our theories, and the basis of our design, has been advanced tremendously by the literature of these years. Early writers on trials of boilers would be amazed to read of the tests of the Connors Creek plant reported in 1922, of the time, the money, the men, the accuracy represented in the few pages of figures which contain the results. Here is but one instance of a great advance, an advance in accuracy and thoroughness of testing, an advance which all investigators can use because most of it is contained in the Society's test codes.

Engineering is old—and empirical; science is young—and exact. The literature of these forty-five years forecasts that progress from empiricism to science which will be the development of engineering from now on. The men who will aid in that advance will have their feet deep in the past and the inspiration of the past will stimulate their larger effort. They will look back with gratitude to these early records; and where they fail to find the answers they seek, they will see the pitfalls that experience exposes and will be saved much of their labor. A later age will record their achievements

in Transactions, and a subsequent Index inscribe their names in the list of worthies between Robert R. Abbott, who heads the present Index, and L. A. Zohe with whom the pages close.

G. A. STETSON.[1]

Breaking the Road

SAID Kipling,

> There's a regiment never listed
> That carries no flag or crest,
> But, split in a thousand detachments,
> Is breaking the road for the rest.

One of these detachments, four men and two planes, is nearing the home country from a flight around the world, as this is being written.

No one questions the courage and skill with which the round-the-world flight has thus far been carried out, but the value of the achievement may not be clear to those not directly concerned with aviation.

It would appear at first sight that if a flight of 500 miles is possible there is nothing especially surprising or noteworthy in the repetition of the same performance fifty times, especially when time is given to overhaul planes and even the engines are replaced during the flight.

Actually, however, the situation is very different. The round-the-world flight has been a searching test not only of the skill and courage of the men but of the state reached by aviation scarcely more than a score of years after the first heavier-than-air flight. The route followed subjected the gallant airmen to practically every conceivable flying condition. The biting cold, mirages, and snow-filled fog of the Alaskan trip, the storms and fogs at Dutch Harbor and the Komodorski Islands, than which there are few worse spots on earth, were overcome only to bring the fliers a few weeks later into the scorching heat of Central India, and the sand storms of the deserts fringing the Indian Ocean. Then followed a couple of thousands of miles of flight over Europe under reasonably comfortable conditions, only to be succeeded by another terrible stretch over Iceland to Reykjavik, where, as this page goes to press, the fliers were held up on their journey owing to ice conditions in Greenland preventing the establishment of a base. It is this abundance of dangers and obstacles rather than the thirty-odd thousand miles covered, which makes the round-the-world flight an achievement. The flight may be considered as a sort of supreme test to prove that aviation has truly come of age.

The men who brought the planes through all these perils and difficulties are entitled to the highest praise. Had the planes broken down for some reason somewhere in the middle of the journey, the pilots would still carry the distinction of having attempted, possibly prematurely, an excessively difficult task. All of them must feel something like Captain Hyde-Pearson, who was killed in March, 1924, while flying with the mail from New York to Cleveland, and who said:

"Every one in the aviation service is doing the world far more good than the public can appreciate. We risk our necks; we give our lives; we perfect a service for the benefit of the people of the world. They, mind you, are the ones who call us fools."

Are Engineers Entitled to Vote?

IT IS a good sign that the engineer is facing the fact that he is neglecting the opportunity to be of service to his community. By temperament, by education, and by habit he waits, wrapped in his toga of technology, for popular clamor to call him to a position of responsibility in guiding the state, but without result. In the presidential address at the last A.S.M.E. Annual Meeting, Mr. Harrington stated the engineers' shortcomings frankly and fully. But Mr. Harrington also pointed out optimistically that the engineering profession is young, is not bound by tradition, and has the courage, the energy, and the orderly and creative mind essential to the solution not only of its own problems but of the great problems of the industrial world.

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Under the heading The High Cost of Having Hoover, an editorial in the July issue of *Mining and Metallurgy* emphasized again the fact that in view of his special qualifications the engineer is negligent of his opportunity for civic duty. The editorial stresses the fact that Hoover's elevation to the Cabinet has made it very simple for the individual engineer to point to Hoover in the Cabinet or to Hartness as former governor of Vermont and regard the work of the engineering profession as finished. But that ability to enjoy the performance of our civic duties by proxy can only come after long periods of gradually becoming more and more calloused to the conduct of public affairs. It is also evident in other activities of human life. Hosts get their physical exercise watching a picked few perform. Thousands get their enjoyment of art by collecting rather than creating. Our music comes from trained bands, or through loud speakers, or from flat disks. And all of this is in spite of what one magazine writer calls "the ineradicable capacity for creative work" which is ingrained deeply—too deeply, perhaps—in human nature. We are "on the side lines," and students of history tell us that the ages when human activities were confined to the side lines were not the greatest ages of civilization.

As far as the engineer and his relation to civic affairs are concerned, the situation has been strongly stated by H. M. Waite, a civil engineer of standing, who, from a four-year period as city manager of Dayton, Ohio, knows whereof he speaks.

> We need the man of practical affairs in public life. We have too many laws. We cannot enforce what we have. What we need now is readjustment. We need the engineering mind to readjust conditions created through the laws passed by lawyers. We need the practical mind to take the present developed country and apply common sense to its readjustment to conditions as they exist today. Engineers cannot do this by discussing papers. They must take a position in public life.
>
> The engineer cannot solve this problem alone but he can help. My belief is, that to get the engineer in a helpful mental attitude it is necessary to preach two things to him: First, that the engineer is not a superior being only to be courted from behind his maze of technical education. The engineer must be educated to give, in a practical way, the knowledge which he has. Second, the engineer must be taught that government is a business, and the only way it is possible to get business methods into government is to have the engineer with business judgment enter public life.

It is easy to be optimistic, but there are some signs that show that the engineer is coming to life. One city of the East has just elected an engineer mayor after a campaign that proved to that community that the engineer has a place in civic affairs. Many local organizations of engineers are officially called upon to advise in important public works. Admittedly these may be isolated cases, but they show a trend. The ideal, however, will come with complete participation of the engineering profession in civic affairs, and in one important relation of the individual to government complete participation is possible. Every citizen engineer is entitled to vote. He can study the issues, political, economic, and social, and register his opinion at the polls. There should be no engineers among the fifty per cent of the electorate who do not vote during the coming fall.

International Power-Test Codes

DURING the past summer London was the scene of two small but important gatherings, one on July 3, to hear a paper by Capt. H. Riall Sankey on the scope and objects of the Heat Engine and Boiler Trials Committee, and the second, on July 5, for the discussion of a standard test code for Hydraulic Power Plants. The presence at these gatherings of members of the A.S.M.E. who are taking a part in revising the A.S.M.E. Power Test Codes of 1915 was very fortunate, for the value of international test codes is recognized and every opportunity for the discussion of the problems involved in establishing standardized testing procedure is an opportunity for the development of engineering science. A test code must be adapted to the requirements and practices of the group of engineers and manufacturers who depend on the code, but there will be points of common agreement between national groups and these should be recorded in the completed testing procedure. Frank and intimate discussion is necessary to bring out the points of agreement which, once established, should lead to further coördination of the various national codes.

The British Heat Engine and Boiler Trials Committee, composed of representatives of eleven British engineering and manufacturing

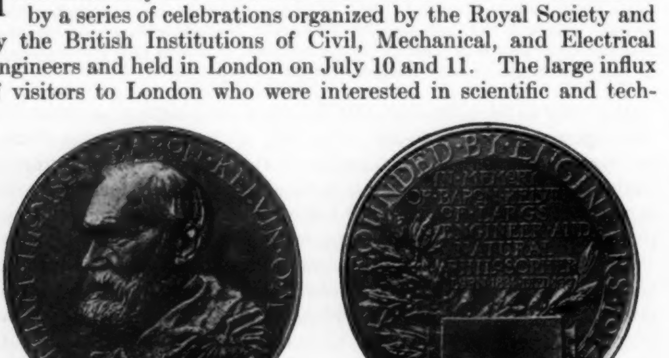
organizations, has been in existence for about two years. It was formed to prepare codes for the standardization of testing of heat engines, not only for commercial trials, but also for the comprehensive tests necessary for scientific purposes. The codes which the Committee will prepare are: Boiler and its Accessories, Steam Reciprocating Engine, Steam Turbine, Condensing Plant, Gas Engine, Gas Producer, Petrol and Paraffin Engine, and Heavy-Oil Engine.

In the discussion on July 3 on different questions asked by the Committee there seemed to be general agreement that the higher heating value of fuel should be adopted, that the expression of "lb. of steam evaporated from and at 212 deg. fahr." should be omitted, and that the term "boiler horsepower" should not be used. On the fourth question, as to the admissibility of steam meters and water meters and comprehensive trials for scientific purposes, records of the meeting indicate that their use would not be encouraged. The Committee has appointed a correspondence committee for the interchange of ideas with the A.S.M.E. Committee on Power Test Codes.

A draft of a standard test code for hydraulic power plants, prepared by a joint committee of the British Institutions of Civil and Mechanical engineers, was submitted for public discussion on July 5. At this gathering, at which there were a large number of American engineers, the matter of an international code was discussed at length. The International Electrotechnical Commission was suggested as the agency for bringing about such a result. The discussion did not emphasize any great difference between the draft code presented for discussion and the Test Code for Hydraulic Power Plants and their Equipment which has been formulated and adopted by four American engineering societies.

The Kelvin Centenary

The centenary of the birth of Lord Kelvin was commemorated by a series of celebrations organized by the Royal Society and by the British Institutions of Civil, Mechanical, and Electrical Engineers and held in London on July 10 and 11. The large influx of visitors to London who were interested in scientific and technical matters swelled the attendance at these testimonials to Lord Kelvin's enduring fame.



The Kelvin Medal

The first event of the program was the presentation of the Kelvin Medal to Dr. Elihu Thomson, which took place on Thursday, July 10, in the Hall of the Institution of Civil Engineers. Sir Charles Morgan, president of that Institution, made the presentation and in his remarks recalled the success of the early days of arc lighting attained by the Thomson-Houston machines and the contributions made by Dr. Thomson in alternating-current practice and welding. In accepting the medal Dr. Thomson stated that he felt that it was a tribute not only to him but to his fellow-workers in America. He pointed out that the engineer was the only professional man who was called upon to guarantee results. The lawyer, the physician, and the clergyman could not give guarantees.

Dr. Thomson is the second recipient of the Kelvin Medal. The first award was made in 1920 to Dr. W. C. Unwin, F.R.S. The fund through which it was established was the balance from a fund for a window which had been placed in Westminster Abbey to the memory of Lord Kelvin by engineers of the British Empire and the United States who had contributed toward it. The Executive Committee of the Memorial Fund decided that the balance should be applied to the establishment of a Kelvin Gold medal, to be awarded triennially as a mark of distinction in engineering work or investigation of the kinds with which Lord Kelvin was especially identified. The Institution of Civil Engineers accepted the trust and administration of the Medal Fund, and it was decided that the award should be dealt with by a committee in London, consisting for the time being of the presidents of the following Institutions: The Institution of Civil Engineers, the Institution of Mechanical Engineers, the Institution of Electrical Engineers, the Institution of Naval Architects, the Iron and Steel Institute, the Institution of Mining and Metallurgy, the Institution of Mining Engineers, and the Institution of Engineers and Shipbuilders in Scotland.

The presentation of the medal was followed by addresses by British and foreign delegates, the chair being occupied by Sir Richard T. Glazebrook, Chairman of the Kelvin Centenary Committee. The Kelvin oration was delivered by Sir J. J. Thomson and took the form of a historical sketch of Kelvin's life and work.

A large group of Kelvin exhibits were shown at the Hall of the Institution of Civil Engineers and among them were a number of electrometers and several types of mirror galvanometers, including the instrument used at sea by Lord Kelvin during the laying of the Atlantic cable. There were also a number of other experimental devices which Lord Kelvin used in instructing his classes at the University of Glasgow.

Later in the evening the Royal Society held a soirée at Burlington House in honor of Lord Kelvin and on Friday evening, July 11, there was a banquet at the Connaught Rooms. The Earl of Balfour presided and presented a notable address. The other speakers were Sir Richard Glazebrook, Dr. Elihu Thomson, Prof. Luigi Lombardi, and Dr. A. E. Kennelly.

S.P.E.E. Holds Important Meeting in Colorado

The thirty-second annual meeting of the Society for the Promotion of Engineering Education was held at the University of Colorado, Boulder, Colo., June 25 to 28. One hundred and fifty members were present from 70 colleges, 38 states, Canada, and Hawaii. The total registration of 362, which exceeded former records, was largely due to the scenic interest of the meeting place.

The feature of the meetings was the presentation of data on educational research rather than papers embodying ideas and opinions. Six-year engineering courses at Columbia University were explained by Dean G. B. Pegram, who pointed out that the work there was highly satisfactory, although few students are graduated. Fifteen years of experience with a five-year engineering curriculum at Northwestern University was reported by Prof. W. H. Burgess and Director J. F. Hayford. Although only 8 per cent of those who enter complete the fifth year, compared with 35 to 40 per cent in the average four-year course, the attendance has shown an average annual increase of 9 per cent.

W. E. Wickenden, Director of the Board of Investigation and Coördination, supported the view that five- or six-year courses are needed for the adequate training of the engineer of the future, but concerted action by the entire profession is needed to make such courses successful. Mr. Wickenden, as chairman of the board to administer the $108,000 fund created by the Carnegie Foundation, presented comprehensive plans for this great research in engineering education. Coöperation of industrial organizations and national engineering societies has been secured and these bodies will assist in analyses of the work of engineers in different occupations. It is hoped to secure sufficient data to determine the true fundamentals of engineering education; then concerted action will be required to put into effect the needed improvements.

The new officers of the society are: President, Dean A. A. Potter, of Purdue University; vice-presidents: Prof. R. S. King, Georgia Institute of Technology, and Dean G. B. Pegram, Columbia University. Members of the council for three years: Dean G. M. Butler, University of Arizona; Prof. H. Pender, University of Pennsylvania; Dean E. B. Norris, State College of Montana; Prof. W. E. Brooke, University of Minnesota; Assistant Dean H. H. Jordan, University of Illinois; Prof. W. H. Kenerson, Brown University, and Director W. E. Wickenden. The secretary, Dean F. L. Bishop, of Pittsburgh, and the treasurer, W. O. Wiley, of New York, were reëlected.

The World Power Conference

THE World Power Conference held in London June 30 to July 12 was, from many points of view, the most notable gathering of its kind ever convened. It attracted large representations of engineers from many nationalities to London, and the various sections of the program reviewed the power problems of the world with a completeness that has never before been attempted.

The Conference was organized by the British Electrical and Allied Manufacturers' Association in coöperation with numerous technical, scientific, and commercial organizations. The purpose was to consider the sources of world power by evaluating the resources of each country, by comparing experiences in the development of scientific agriculture, irrigation, and transportation, by engineering conferences, by consultations of power consumers and power-machinery manufacturers, by financial and economic discussions, and by conferences looking to the establishment of a permanent world bureau for the collection of data and the exchange of industrial and scientific information.

The Conference was formally opened on Monday afternoon, June 30, by the Prince of Wales in the large conference room of the British Empire Exhibition. Lord Derby, President of the Conference, presided at this ceremony. In his address the Prince of Wales extended a cordial welcome to the delegates to the Conference and expressed the hope that the personal contacts gained during the discussions would form the inspiring motive of progress in every great activity connected with modern industry. Sir Joseph Cook responded on behalf of the British Dominions, Dr. G. Semenza of Italy spoke for the European countries, and O. C. Merrill, of the United States replied for the Americas. Mr. Merrill received considerable applause when he stated that mutual understanding was badly needed in the world at the present time and that contacts between people more than contacts between governments would bring about that understanding.

More than four hundred papers were presented from over forty countries, which were classified for discussion under the following headings: Power Resources, Power Production, Power Transmission and Distribution, Power Utilization, and General. Under this last heading financial, economic, and legal considerations were discussed, as were also research, standardization, education, health, and publicity. In the Survey of Engineering Progress in this issue will be found very brief abstracts of some of the foreign papers which deal with topics of outstanding importance. Forty papers presented by American authors summarized the results of American progress in power generation, transmission, and utilization, and included a summary of American resources. The complete proceedings of the Conference will be included in four volumes approximating 5500 pages, which are to be published by Perry Lund, Humphries & Company, Ltd., 3, Amen Corner, London E. C. 4, England. The price, ordered before September 1, 1924, is £ 10; if ordered later, £ 12. The publishers will send a prospectus of contents upon application.

The technical sessions were held mornings and afternoons, sometimes three at a time, on the first ten weekdays of July. The meeting places were the conference halls at the British Empire Exhibition. The papers, which had been printed in advance, were presented by title and thrown open to discussion by the delegates present. Over one hundred and seventy-five Americans were at the Conference and many of them participated actively in the technical sessions. Among the presiding officers were George Otis Smith, Director of the U. S. Geological Survey; David S. Jacobus, John W. Lieb, John R. Freeman, Fred R. Low, Joseph W. Roe, and R. A. Millikan. Arthur Surveyer, president of the Engineering Institute of Canada, presided at one of the sessions on Water Power Resources. Among those who discussed the various papers were W. L. R. Emmet, David Rushmore, W. S. Murray, Sanford Riley, O. F. Junggren, Geo. A. Orrok, and Lieut. R. B. Alexander.

At the concluding sessions, which were held Friday, July 11, there was a review of the activities of the previous day's sessions and plans for future development were considered. At this session Mr. Merrill pointed out that the papers and discussions would be a source of reference to engineers and other for many years to come. Each country had brought its own contribution and the questions had been discussed in a spirit of confidence and coöperation. There had been general recognition of the fact that scientific knowledge was common property and should be used for the common purposes of mankind. Resolutions were passed asking that each country which participated in the Conference create and maintain a permanent national power committee from which delegates would be appointed on an international executive committee which would, for the time being, carry out the necessary work arising from the Conference. Another resolution recommended that the organization which had convened the London Conference should remain as an organization during the transitional period. The following general resolution was unanimously carried: "That this Conference is of the opinion that the world's most crying need today is greater production and manufacturing activity among its peoples under conditions which will promote individual prosperity and happiness, and that this can be largely achieved by the fuller development of national power resources and by the establishment of the most economical means for the general distribution and utilization of energy."

SOCIAL EVENTS

The strenuous work of the technical sessions was relieved by a number of receptions, luncheons, banquets, and other social features arranged by British organizations. These formed a valuable part of the Conference as they permitted the development of acquaintances which should be one of the permanent results of the London meetings. The first social event was the opening banquet of the World Power Conference on the evening of June 30. Lord Derby presided and Samuel Insull was on the list of speakers from America. The attendance at this affair was over eight hundred. The American Committee tendered a banquet in honor of the delegates from other countries on Thursday evening, July 3. O. C. Merrill, General Chairman of the American Committee, presided and Dr. Arthur T. Hadley, former President of Yale University, gave the address of welcome. P. J. Pybus, Dr. M. Kamo, Em. Uytborck, and John Murphy responded. Henry J. Pierce and Dr. A. E. Kennelly also spoke. On Friday, July 4, the Canadian Committee tendered a luncheon to the delegates and on Tuesday, the 8th, the Italian Committee gave a reception.

The American visitors to London were invited to the annual Independence Day dinner of the American Society in London on July 4. Hon. Frank B. Kellogg, American Ambassador, was chairman of this event. Right Hon. John H. Thomas, Secretary of State for the Colonies, and the Dean of Windsor were the speakers.

The summer meeting of the Institution of Mechanical Engineers was held from July 7 through 9, and is treated more completely in another column, as is the Kelvin Centenary.

There were many other events of great interest to the American visitors in London during the time of the Conference, such as the meeting of the Institution of Civil Engineers on July 8 at which Dr. Elihu Thomson delivered the James Forrest Lecture entitled Electrical Progress and Its Unsolved Problems, the Conversazione on July 15 by invitation of the Institutions of Civil, Mechanical, and Electrical Engineers, and the visits to points of interest in and about London that were planned by the Institution of Electrical Engineers.

Appreciation of the generous hospitality was expressed many times by the visitors and the careful and thoughtful manner in which the events were carried out made for the general success of the Conference. Trips to Switzerland, France, Italy, Norway, Sweden, as well as through England and Scotland, had been arranged to follow the World Power Conference, and the majority of the Americans participated in these trips.

Success Marks Prague Management Congress

THE first International Management Congress, held in Prague, Czechoslovakia, July 20 through 24, was reported as a tremendous success. The registration of over eight hundred from fifteen countries and an attendance of five hundred at the sessions are an indication of the interest in management in central Europe. About forty engineers from the United States participated in the Congress, the program for which presented the most advanced methods of management developed by American industry.

The official invitation to participate in the Congress was extended

by the Government of the Republic of Czechoslovakia and the Masaryk Academy through the American Engineering Council to the Four Founder Societies and to the member societies of the American Engineering Council. The Four Founder Societies in turn requested that representatives of organization and American participation should be represented by a general committee on American participation consisting of representatives of American Management Association, the Management Division of the A.S.M.E., the National Association of Cost Accountants, the Society of Industrial Engineers, and the Taylor Society.

Dr. Vaclav Verunac of the Masaryk Academy greeted the visitors from the United States and from Jugoslavia, Poland, Rumania, and Russia, and expressed the hope that the Congress would be a first step toward clearness in the sphere of world economic reconstruction and by engineering methods work for world cooperation. Stanley Spacek expressed the appreciation of the Czechoslovakian Committee for the efforts of the American Committee in preparing the program. Dr. J. Basta, President of the Masaryk Academy of Work gave a tribute to Frank B. Gilbreth who had been active in the work of planning the program.

The papers presented by the Americans were as follows: Scientific Management—Nature, Achievements and Tendencies, Fred J. Miller; Industrial Research in the United States, Maurice Holland; Individual Relations in Industry, Henry C. Link; Labor Relationships in American Industry, Edward S. Cowdrick; The Development of an Industrial Budgetary Control, Howard Coonley; Production Control, G. Babcock; Belting: Purchase, Maintenance, Power and Methods of Obtaining Complete Data upon its Performance, W. W. Nichols; Sales Management, C. K. Woodbridge; Management in the Coal Industry, Sanford E. Thompson; Some Problems of American Railway Management, Roy V. Wright; The Problem of Efficient National Administration, W. F. Willoughby; United States Department of Commerce and Its Relation to Business, H. Lawrence Groves; The Role of Machinery in American Agriculture, H. R. Tolley; Education for the Profession of Engineering, Wm. W. Wickenden; Vocational Education, C. R. Dooley; Advanced and Specialized Education for Commerce and Business Administration in Universities, Colleges, and Schools of Engineering, George W. Coleman. These papers were very fully discussed at the Congress. It is planned to collect them in a volume of proceedings which will be available in the near future.

Among those who presided at the various sessions were Dr. H. S. Person, Roy V. Wright, Prof. Joseph W. Roe, Calvin W. Rice, George W. Coleman, Robert T. Kent, L. W. Wallace, and Mrs. L. M. Gilbreth.

Following the Congress a program of visits to Czechoslovakian manufacturing plants proved of great interest to the American delegates.

Northeastern Superpower Report

As THE result of a conference in October, 1923, between Secretary Herbert Hoover and chairmen of the State Utility Commissions of the eleven northeastern states, the Northeast Superpower Committee was formed with representatives of the various State Utility Commissions and their related official agencies. There were also representatives from the Federal Power Commission, the United States Geological Survey, and the United States Army. This Committee appointed an engineers' sub-committee which undertook a comprehensive survey of the technical aspects of superpower development in the states affected. Their report, now made public, will be taken up at the meeting of the full committee some time in the fall.

The survey covers the states of Maine, New Hampshire, Vermont, Massachusetts, Rhode Island, Connecticut, New York, New Jersey, Pennsylvania, Delaware, and Maryland, and the District of Columbia. There has been included also some reference to the states of Ohio, Virginia, and West Virginia, since under certain circumstances power in these regions will be contributory. Forty per cent of the country's population, consuming fifty per cent of the nation's electrical power production and operating sixty per cent of the primary power of the whole country, is concentrated in this particular area.

In this territory 21.2 billion kw-hr. of electrical energy was produced in 1922, of which 5.2 billion kw-hr. was produced from water power. In addition industry, not including railroads, used 13.9 billion kw-hr. of mechanical power which could to some extent be advantageously replaced by electric power. 17.75 billion kw-hr., or 84 per cent of the total, is consumed in nine load centers. A study of the report shows that electric power applications have compounded at the rate of 10 per cent per annum for the last decade, indicating that the total electric power demand in 1930, not including possible electrification of the railways, will be 30.8 million kw-hr.

The demand for electrical power within this area is supplied from water and from coal. The present developed water power is about 3,036,000 hp.; the total potential water power available 90 per cent of the time is 5,426,000 hp. This is increased to 7,914,000 hp. available 50 per cent of the time.

At present about 38 per cent of the total water power ultimately available in this area has been developed. But practical development of water power will probably be such that not over 25 per cent of the total power demand in any year can be met from this source. Principal dependence, therefore, must be placed upon generation of power from coal.

There are in this area nearly two hundred different utility companies engaged in power production and distribution, many under common ownership. Of these about 45 per cent are technically interconnected, but only about 8 per cent of the interconnections have capacity large enough for effective interchange of power. Great economies in cost of production can be secured from the early effective interconnection of these utility systems, which in some cases will involve larger and systematic high-voltage transmission.

Such interconnection will lead to the reduction of the amount of reserve equipment, better average load factor through pooling of daily and seasonal load variation and wide diversification of use through increased industrial consumption, and more security in power supply against interruption by many causes. It will also mean that available water power in the area can be much more advantageously applied to carry base or peak load as local conditions may require. It should make possible the use of secondary water power which arises from the seasonal flow of streams, and thus bring into practical use a larger quantity of water power than would otherwise be possible. Finally, power would be available more quickly to meet growing demands.

The economic generation and distribution of power vitally requires that it be produced in large plants. Present practice indicates that such plants should be constructed with total capacities of from 200,000 to 500,000 kw., using generators of not less than 20,000 kw. each. Because great plants of this character require immense quantities of water for condensation purposes, their location will be controlled by considerations of water supply. A study of available water supply has led the engineers to the conclusion that the location of such plants will accordingly be restricted to areas along the seaboard, the Great Lakes, the Ohio River and its tributaries, and the Susquehanna River. The generation of power at the coal fields in western Pennsylvania, Ohio, and West Virginia, and in plants on the Ohio River and its tributaries will, according to the report, become an important factor in a large area because of the savings in coal transportation. This problem as it affects the coastal area becomes one of relative costs of electrical power transmission and of coal transportation. Some difference of opinion exists as to the distance power generated at the coal fields can be advantageously transmitted.

Turning from steam plants to a discussion of water power, the engineers declare that the large demand affords an immediate market for the cheaper water power from the larger projects and renders their development both urgent and necessary. At the same time the large use of steam in the area makes possible the use of the seasonal flow of rivers for relief of steam, and thus enables more complete utilization of the rivers than in any other part of the United States. Interconnection in some cases will convert secondary hydro power into primary power, and in other cases will enable daily peak loads to be carried on hydro. The great water powers capable of expansion, according to the report, are: The Niagara River, the St. Lawrence River, the Delaware River, the Susquehanna River, the tributaries of the upper Ohio, the rivers of the Adirondacks, the Potomac River, and the rivers of Maine.

John H. Dunlap

JOHN H. DUNLAP, Secretary of the American Society of Civil Engineers for the past two years, died in Chicago on July 29, 1924, from injuries received on June 30 in a railroad accident at Buda, Illinois, while returning from the annual meeting of the Society for the Promotion of Engineering Education at Boulder, Colorado.

Mr. Dunlap was born September 9, 1882, in Harrisville, New Hampshire. In 1905 he was graduated from Dartmouth College, and three years later received his degree from Thayer School of Civil Engineering. Most of his life was spent in university work. For a year he served as field instructor in surveying at Thayer School and for fourteen years he was on the faculty of State University of Iowa, beginning his career there as an instructor in descriptive geometry and winning his promotions until he became professor of hydraulics and sanitary engineering in the College of Applied Science at that institution. During that period he devoted part of his time to private practice as a civil and sanitary engineer.

His election in 1922 as secretary of the American Society of Civil Engineers was in recognition of his successful work and the inherent qualities which fitted him so admirably for an executive position of this type. His unselfish devotion to the highest ideals of the engineering profession and the best interests of the Society won for him the admiration of its membership, while his desire for mutual coöperation in bringing his ideals to realization won the respect of those of the outside world with whom he came in contact.

John H. Dunlap

Mr. Dunlap's two brief years of service to the American Society of Civil Engineers were years of accomplishment and of great promise. The loss created by his untimely death is acknowledged in the following resolutions:

Whereas, It has pleased Almighty God to take from us our beloved Secretary, John Hoffman Dunlap, be it

Resolved, That the President and the Executive Committee, in behalf of the Board of Direction and the members of the American Society of Civil Engineers, express their sense of the great loss which the Society and the Engineering Profession of the United States has suffered by the death of our Secretary, who by his labors in our behalf; by his faithfulness, efficiency and courtesy; by his advocacy of the highest ideals for the advancement of the Profession; by his unselfish efforts to serve every member of the Society; and by the example he set us as a Christian citizen, has made a lasting impression in our hearts. Be it further

Resolved, That our heartfelt sympathy be extended to his family, that his family be furnished with a copy of this resolution, and that it be spread upon our records, printed in the "Proceedings" and "Transactions" and that copies be furnished to the technical press and to other Engineering Societies.

Benjamin G. Lamme

BENJAMIN G. LAMME, whose death on July 8, 1924, was noted in the August issue of Mechanical Engineering, was one of the world's leading electrical authorities. His practical genius was discovered by the late Albert Schmid in the Westinghouse test room where Mr. Lamme began work.

Although methods for calculating the performance of electric motors and generators were then unknown, Mr. Lamme devised a means whereby the saturation curves of existing machines could be checked from test data. In January, 1890, just eight months after entering upon electrical work, he prepared specifications from calculations for a double-reduction railway motor which was built and placed on the market as a commercial machine. Then from his calculations in the fall of 1890 came the four-pole, single-reduction-gear railway motor with slotted armature, machine-wound coils, and a wave of two-circuit winding—the design still standard in railway work.

Mr. Lamme was a prolific inventor, 150 patents standing to his credit. He was largely instrumental in the perfection of many alternating-current devices. Numbered among his early achievements were the design of lighting and generating equipment for the World's Fair in Chicago, in 1893, and the design of the famous "umbrella-type" generators for use when Niagara Falls was first harnessed for water power. He also designed the generating and motor equipment for the first big railway electrification, that of the New York, New Haven & Hartford Railroad, following this by electrification work on the Paoli section of the Pennsylvania Railroad and on the Norfolk & Western Railroad.

Benjamin G. Lamme

About the year 1895 Mr. Lamme conceived the idea that led to the development of the well-known induction motor with the squirrel-cage rotor. His paper on induction motors written about that time is recognized as a standard work and included in Naval Academy textbooks. He regarded his work on the synchronous converter as one of his greatest achievements, for after a hard and almost single-handed battle he won out, and this is now the accepted machinery for converting alternating into direct current.

Next came his conception of the single-phase alternating-current railway system. He succeeded in designing a series commutator type of motor with suitable characteristics which he described along with the system of power distribution in a famous paper given before the A.I.E.E.

He was made assistant chief engineer of the Westinghouse Co. in 1900 and chief engineer in 1903. One of his most recent tasks was the design of the 62,500-kva. generator recently put into operation at the Hudson Ave. station of the Brooklyn Edison Co.

Harris J. Ryan, of Stanford University, president of the A.I.E.E., in paying tribute to Mr. Lamme, says:

"Through the untimely death of Benjamin Garver Lamme, the American Institute of Electrical Engineers and the world of industry, progress and human helpfulness have suffered a loss too great to express in full measure. His life and work will ever stand as a glorious example of the education and working spirit of the modern engineer. He was endowed with an extraordinary supply of well-directed optimism, resourcefulness and good judgment. To him difficulties and limitations were but signals for the next line of advance. In electrical machinery he accomplished the effective coördination of theory and practice in commutation, choice of speeds, frequencies, and a host of related factors. He defined the need and found expediency for the development of the direct-current, single-gear reduction and the single-phase, alternating-current motors and the 60-cycle synchronous converter. Mr. Lamme maintained a lifelong interest in the education and training of the engineer. In a classical paper presented to the A.I.E.E. on the technical training of engineers he made a powerful presentation of the results of his observations with directness and simplicity."

In the previous note on Mr. Lamme's death, the statement was erroneously made that the Sullivant medal had also been awarded to Edison and Steinmetz. Mr. Lamme was the only recipient of this honor.

Engineering and Industrial Standardization

Involute Gears—Proposed Standard Proportions for Stub- and Full-Depth-Tooth Forms

STANDARDIZATION of all types of gears is being carried forward by the Sectional Committee on the Standardization of Gears. This Committee was organized in June, 1921, by the American Gear Manufacturers Association and The American Society of Mechanical Engineers under the procedure of the American Engineering Standards Committee. B. F. Waterman is its chairman and J. P. Kottcamp, secretary.

The various divisions of this project have been assigned to sub-committees which now number ten. H. J. Eberhardt is chairman of the Sub-Committee on the Tooth Form of Spur Gears, and his associates are Messrs. E. W. Miller and G. M. Eaton. This sub-committee has received the following two recommendations from a similar committee of the American Gear Manufacturers Association. However, before it frames its recommendations on tooth form for the Sectional Committee it desires to secure criticism and comment on these proposals of the A. G. M. A. Committee from the readers of Mechanical Engineering.

PROPOSED STUB-TOOTH PROPORTIONS FOR SPUR GEARS

		Diametral Pitch	Circular Pitch
1	Addendum	$= \frac{0.8 \text{ in.}}{\text{D.P.}}$	0.2546 in. × C. P.
2	Dedendum	$= \frac{1 \text{ in.}}{\text{D.P.}}$	0.3183 in. × C. P.
3	Working Depth	$= \frac{1.6 \text{ in.}}{\text{D.P.}}$	0.5092 in. × C. P.
4	Total Depth	$= \frac{1.8 \text{ in.}}{\text{D.P.}}$	0.5729 in. × C. P.
5	Pitch Diameter	$= \frac{\text{N}}{\text{D.P.}}$	0.3183 in. × N × C. P.
6	Outside Diameter	$= \frac{\text{N} + 1.6 \text{ in.}}{\text{D.P.}}$	P. D. + (2 × Addendums)
7	The use of both diametral and circular pitches. (See Note 3.)		
8	A pressure angle of 20 deg.		

PROPOSED FULL-DEPTH-TOOTH PROPORTIONS FOR SPUR GEARS

		Diametral Pitch	Circular Pitch
1	Addendum	$= \frac{1 \text{ in.}}{\text{D.P.}}$	0.3183 in. × C. P.
2	Minimum Dedendum	$= \frac{1.157 \text{ in.}}{\text{D.P.}}$	0.3683 in. × C. P.
3	Working Depth	$= \frac{2 \text{ in.}}{\text{D.P.}}$	0.6366 in. × C. P.
4	Minimum Total Depth	$= \frac{2.157 \text{ in.}}{\text{D.P.}}$	0.6866 in. × C. P.
5	Pitch Diameter	$= \frac{\text{N}}{\text{D.P.}}$	0.3183 in. × N × C. P.
6	Outside Diameter	$= \frac{\text{N} + 2}{\text{D.P.}}$	0.3183 in. × (N + 2) × C. P.
7	Basic Tooth Thickness on Pitch Line	$= \frac{1.5708 \text{ in.}}{\text{D.P.}}$	0.5 in. × C. P.
8	Minimum Clearance	$= \frac{0.157 \text{ in.}}{\text{D.P.}}$	0.05 in. × C. P.
9	The use of both diametral and circular pitches. (See Note 3.)		

Note 1. The above proportions are identical with those of the Recommended Practice for Herringbone Gears.

Note 2. A minimum root clearance of 0.2 in. ÷ D. P. is recommended for new cutters and gears. There is correct tooth action, however, between gears cut to this new system and those cut to the older Nuttall system, the only dimensions affected being the clearance. Where the proposed gear runs with the Nuttall there is a clearance of 0.1425 in./D. P., and where the Nuttall gear runs with the proposed gear the clearance is 0.2146 in./D. P.

Note 3. Term "Diametral Pitch" used to 1 D.P., inclusive. Term "Circular Pitch" used for 3 in. C. P. and over.

Note 4. Suitable working tolerances must be specified in connection with all minimum requirements.

These committees have listed and studied at least nine stub-tooth systems now in use in the United States and Canada, and a considerable number of full-depth-tooth systems. The proportions which are proposed above for discussion have received the unanimous indorsement of the members of both committees.

All those who have had experience in the design and manufacture of spur gears are urged to give this Sub-Committee the benefit of such experience so that the "American Standard" which is finally approved will be the best that industry can produce at this time. These replies should be addressed to H. J. Eberhardt, Secretary-Engineer, The Newark Gear Cutting Machine Company, 69 Prospect Street, Newark, N. J.

Recommended Minimum Requirements for Plumbing

THE Department of Commerce Report on Plumbing Installations contains, in addition to a recommended plumbing code for adoption by cities and states, an extensive report by the Bureau of Standards giving the procedure and results of experiments with plumbing systems carried on for over two years at the Bureau.

The report also presents a considerable amount of data and discussion interpreting the results of this experimental work and showing how the Committee arrives at its recommendations for code revision. There are chapters on the lack of uniformity and agreement in present plumbing codes and on the desirability of simplification of plumbing supplies and fixtures. The report discusses the relation of plumbing to health and the considerations involved in licensing of plumbers, and plumbing inspection as a means of code enforcement. The appendices describe recent developments in theory of corrosion of metals, and investigations of the diffusion of gases in unventilated pipes.

A great part of the information developed by the Bureau of Standards investigation and most of the recommended code requirements apply to plumbing in large buildings as well as to that in dwellings. Considerable attention was given to methods of predicting the loads on plumbing systems and some data are given on conditions of use in large buildings.

Among other interesting facts it was discovered that the fall of water in partially filled pipes has a maximum velocity limit which soon attained and is not affected by the height of the building above a certain point. It also was discovered that the decrease in size of soil stacks found possible permitted a greater proportionate decrease in the size of vent stacks necessary to relieve undesirable pneumatic conditions in the soil stack or its branches. Three-inch soil stacks were found adequate under quite varied conditions, and are permitted by the recommended code for use throughout in dwellings instead of the 4-in. size now generally customary. Proportionate decreases in pipe sizes for larger structures are indicated as feasible. The Committee recommends also that the running or house trap now required in many cities be omitted and that a distance of not to exceed 5 ft. be permitted between traps and ventilation pipes. As a result of tests with complete household systems it was found possible to eliminate much of the expensive vent piping now considered necessary. Economies possible through complete adoption of the Committee's recommendations are estimated at from \$50 to \$100 for a two-story dwelling with the usual number of fixtures, depending on the nature of requirements now obtaining in a given locality.

This report results from a widespread feeling that present state and municipal code requirements are in some respects unnecessarily restrictive and that conservation of labor and materials could be effected by scientific investigation of the burdens on such systems, and their performance under conditions of use. It is well known that the codes of different localities vary widely and that practices forbidden in some places are successfully employed elsewhere.

The report contains 260 pages of text and 100 illustrations, mostly given in connection with the report of experiments at the Bureau of Standards. It may be obtained from the Superintendent of Documents, Washington, D. C., for 35 cents per copy. Remittances should be by currency or money order.

Library Notes and Book Reviews

THE Library is a coöperative activity of the A.S.C.E., the A.I.M.E., the A.S.M.E. and the A.I.E.E. It is administered by the United Engineering Society as a public reference library of engineering and the allied sciences. It contains 150,000 volumes and pamphlets and receives currently most of the important periodicals in its field. It is housed in the Engineering Societies Building, 29 West 39th St., New York, N. Y. In order to place its resources at the disposal of those unable to visit it in person, the Library is prepared to furnish lists of references to engineering subjects, copies of translations of articles, and similar assistance. Charges sufficient to cover the cost of this work are made.

The Library maintains a collection of modern technical books which may be rented by members residing in North America. A rental of five cents a day, plus transportation, is charged. In asking for information, letters should be made as definite as possible, so that the investigator may understand clearly what is desired.

Books Received in the Library

Arc Welding Handbook. By C. J. Holslag. McGraw-Hill Book Co., New York, 1924. Fabrikoid, 5 × 8 in., 250 pp., illus., $2.

A simple, practical manual, which explains the methods step by step, so that the beginner may understand the equipment and the processes. The book is intended for welders and students in trade schools, and also as a guide to engineers and designers in the use of arc welding.

Crain's Market Data Book and Directory of Class, Trade and Technical Publications. Fourth edition. G. D. Crain, Jr., Chicago, 1924. Cloth, 6 × 9 in., 505 pp., $5.

This book is intended to furnish the salient data on production and consumption in the more important American industries and to provide a classified directory of class and technical periodicals, with complete information about circulation, advertising rates, etc. It will enable the manufacturer to ascertain readily the market probabilities in many lines and to select the most suitable journals in which to advertise his products.

Elasticity and Strength of Materials Used in Engineering Construction, Section IV: Columns. By C. A. P. Turner. Published by the author, Minneapolis, Minn., 1924. Cloth, 6 × 9 in., 134 pp., illus., diagrams, tables, $5.

In this volume, consisting of chapters 17 to 22 of the complete work, the author discusses the combined stresses in columns, the economic theory of steel columns, the influence of furnace practice and rolling temperature upon the physical properties of steel, the determination of the quality of steel, economic practice as determined by tests of large bridge columns, reinforced-concrete columns, eyebars, pins and rivet joints.

Handbuch des Wasserbaues. By Hubert Engels. Third edition. Wilhelm Engelmann, Leipzig, 1923. Cloth, 7 × 10 in., 2 v., illus., diagrams, tables, 61 fr.

These two large volumes present an interesting attempt to cover the entire subject of hydraulic engineering in a unified way, with proper proportion for each division of the subject. Two editions were exhausted in less than eight years, showing that the book has found a place. In general plan and style of the book is similar to the well-known Handbuch der Ingenieurwissenschaften. The text is copiously illustrated with clear drawings and each subject is provided with a good list of references. The book is divided into ten main divisions: The Occurrence and Movement of Waters; Hydrology; River Works; Dams; Protection of Land; Agricultural Hydraulic Works; Navigation Works; Ship Locks; Canalization of Streams and Ship Canals; Harbors.

Industrial Physics: Heat. By L. R. Smith. McGraw-Hill Book Co., New York, 1924. Cloth, 5 × 8 in., 283 pp., illus., $2.

An elementary textbook written for technical and vocational schools, in which the practical applications of heat are emphasized. Much space is given to steam boilers and engines, to internal-combustion engines and to automobiles.

Pierre Curie. By Marie Curie. Translated by Charlotte and Vernon Kellogg. Macmillan Co., New York, 1923. Cloth, 6 × 9 in., 242 pp., illus., portraits, $2.50.

This brief biography gives a simple account of Curie's life, with the emphasis on his scientific achievements rather than on the man himself. The volume also contains a short autobiography of Madame Curie. As a whole, the book is a history of the discovery of radium.

Die Rationalisierung im Deutschen Werkzeugmaschinenbau. By Fritz Wegeleben. Julius Springer, Berlin, 1924. Paper, 6 × 10 in., 172 pp., $1.45.

This work is a presentation of "American" methods of organization and management, illustrated by the practice of the Ludwig Loewe Company, the first firm to adopt them in Germany. The book discusses the trend of development in industrial organization, standardization, specialization, methods of increasing productivity, personnel management, welfare work, wage systems, etc. The author writes from long experience as a factory manager and as a student of economics; he attempts to select essentials from the great diversity of problems connected with the rationalizing of industry and to present these with an appreciation of their economic significance.

Reinforced Concrete and Masonry Structures. By George A. Hool and W. S. Kinne. McGraw-Hill Book Co., New York, 1924. Cloth 6 × 9 in., 886 pp., illus., diagrams, tables, $6.

The topics covered in this volume include the preparation and placing of concrete forms, bending and placing reinforcement, finishing and waterproofing, building construction, retaining walls, slab and girder bridges, arches, hydraulic structures, chimneys, detailing and estimating. The book is the work of a number of specialists, who have combined to produce a thorough description of modern methods of design and construction, suited for use as a reference book by students and engineers.

Traité de Stabilite du Matériel des Chemins de fer. By Georges Marié. Ch. Béranger, Paris and Liége, 1924. Cloth, 7× 11 in., 579 pp., diagrams.

The author of this work has long been a student of the question of the oscillations of steam and electric rolling stock at high speeds and has published a number of papers on phases of the problem during the past twenty years, for which he has been awarded prizes by the Institut de France and the Société des Ingénieurs Civils de France. In the present book the substance of these memoirs is included with other material in an extended study of the influence of the various elements of the track on train stability. The author analyzes the factors that control safe speed and shows how speeds may be increased by more careful design of roadway and rolling stock.

Welding Encyclopedia. Fourth edition. By L. B. Mackenzie and H. S. Card. Welding Engineer Publishing Co., Chicago, 1924. Fabrikoid, 6 × 9 in., 435 pp., illus., $5.

This new edition appears less than a year after the third, owing to the latter having become exhausted. Additions have been made to the rules and regulations affecting the industry and of methods for procedure in a number of important jobs of railroad welding. The book is a convenient digest of present developments in welding, accompanied by working instructions for the operations commonly found in the industries, the official rules and regulations covering welding, and a training course for welders. The book covers not only arc and resistance electric welding but oxy-acetylene and thermit welding.

THE ENGINEERING INDEX

Registered United States Great Britain and Canada

Exigencies of publication make it necessary to put the main body of The Engineering Index (p. 127-EI of the advertising section) into type considerably in advance of the date of issue of "Mechanical Engineering." To bring this service more nearly up to date is the purpose of this supplementary page of items covering the more important articles appearing in journals received up to the third day prior to going to press.

AIRPLANE ENGINES

High-Power. Progress Toward 1,000-Hp. Aircraft Engines, G. D. Angle. Am. Mach., vol. 61, no. 5, July 31, 1924, pp. 181–184, 6 figs. Advancement since war of design and construction of high-power engines for use in large aircraft for any purpose.

Wright. A New Type of Engine for Large Aircraft, G. D. Angle. Aviation, vol. 17, no. 5, Aug. 4, 1924, pp. 832–834, 4 figs. Gives main features of 80-deg. W type engine of 18 cylinders.

AIRPLANES

Commercial. The Glenn L. Martin Model 70 Commercial Plane. Aviation, vol. 17, no. 5, Aug. 4, 1924, pp. 835–836, 1 fig. New ship designed for either cargo or passenger carrying, 200-hp. Wright model E4 engine with pay-load capacity of 750 lb. and cruising range of 550 miles.

Refueling in Flight. Practical Value of Refueling Airplanes in Flight, H. H. Arnold. Aviation, vol. 17, no. 2, July 14, 1924, pp. 750–751, 1 fig. Discusses desirability of refueling during flight from fuel-carrying planes.

AUTOMOBILE ENGINES

Fins, Cooling Capacity of. How to Determine the Cooling Capacity of Fins on Crankcase or Engine, C. B. Dicksee. Automotive Industries, vol. 51, no. 4, July 24, 1924, pp. 206–210, 11 figs. Substitution of copper for cast iron or steel does not yield great increase in heat dissipation unless number of fins is multiplied and their thickness decreased.

AUTOMOBILES

Brakes. Action of New Air Brake Dependent on Motion of Vehicle. Automotive Industries, vol. 51, no. 3, July 17, 1924, pp. 165–169, 8 figs. Describes new air brake brought out by Knorr Bremse A. G. of Berlin-Lichtenberg. Road wheels cannot lock; horn is sounded automatically with brakes in emergency position; designer has worked out types for various classes of motor vehicle and also for trailers.

Transmissions. New Transmission Allows for Changing Gears without Interrupting Torque. Automotive Industries, vol. 51, no. 3, July 17, 1924, pp. 144–145, 3 figs. New clutch-transmission combination developed by Automatic Clutch & Transmission Co. Direct and hydraulic drive combined in such a way that latter works automatically at low speeds in starting and under heavy load.

BOILER PLANTS

Steam Accumulation. Steam Accumulation, J. Ruths. Engineering, vol. 118, no. 3054, July 11, 1924, pp. 68–69, 3 figs. Equalizing ability of steam boilers of various types as compared with that of accumulators; description of accumulator; special uses of accumulator in power plant, and results obtained in practice. Paper, abridged, contributed to World Power Conference.

CASE-HARDENING

Steel. The Case-Hardening of Steel by Boron and Nitrogen, T. P. Campbell and H. Fay. Indus. & Eng. Chem., vol. 16, no. 7, July 1924, pp. 719–723, 5 figs. Experiments on low-carbon steels show that boron penetrates like carbon, but boron steels are less hard; and that nitrogen is more readily absorbed by boron steel than by carbon steel.

CAST IRON

Tensile Strength. Strength of Cast Iron and Its Thickness, W. Rother. Iron Age, vol. 114, no. 6, Aug. 7, 1924, pp. 326–327, 5 figs. Investigation of relation between physical properties as affected by graphitic carbon; arbitration and experimental test bars.

CENTRAL STATIONS

England. The North Tees Power Station. Engineering, vol. 117, no. 3050, and vol. 118, no. 3054, June 13 and July 11, 1924, pp. 753–755 and 57–59, 14 figs. partly on supp. plate. General description of power station of North-Eastern Power Cos., with particulars of its layout and equipment; design from thermodynamic point of view. See also Engineer, vol. 137, no. 3572, June 13, 1924, pp. 664–665, 4 figs.

High Pressures and Temperatures in. High Pressures and High Temperatures in Central Stations, W. S. Monroe. Power, vol. 60, no. 3, July 15, 1924, pp. 87–91, 6 figs. Discusses reheating and regenerative cycles, describes arrangement employed at Crawford Ave. Station and shows why initial cost with 550 or 600 lb. need be but little more than with 300 lb. pressure. From paper read before World Power Conference.

Saginaw River, Mich. Saginaw River Steam Plant of Consumers Power Company. Power, vol. 60, no. 4, July 22, 1924, pp. 122–129, 7 figs. This new steam generating station has recently put in operation an initial 40,000-kw. installation of a 100,000-kw. plant, featured by preheating of feedwater and combustion air with steam bled from three stages of main turbines, conservation of radiated and blow-off heat, water sides in boiler furnaces, sluicing of ashes, and two motor-driven fans. Table giving data on principal equipment.

DIES

Drawing. The Redevelopment of the Drawing Die, S. S. Erpward. Forging—Stamping—Heat Treating, vol. 10, no. 8, Aug. 1924, pp. 292–294, 6 figs. Highest attainment in development of drawing dies may be traced to demands of automobile manufacturer for quantity production.

Drop-Forging. Drop-Forging Dies—Layout and Design, W. Anslow. Forging—Stamping—Heat Treating, vol. 10, no. 7, July 1924, pp. 250–254, 18 figs. Parting line, contraction and balance are important considerations in laying out dies. Life of dies is, to a large extent, dependent upon their design. Reprinted from Jl. of (British) Assn. Drop Forgers & Stampers.

DIESEL ENGINES

Developments. The Diesel Engine, A. Nagel. Engineering, vol. 118, no. 3055, July 18, 1924, pp. 110–112, 4 figs. Discusses recent improvements in Diesel engine construction, including (1) freeing main type engine of handicaps due to too close adherence to original model, (2) use of two-stroke cycle for large engines, (3) injection and atomizing of fuel without aid of compressed air, (4) use of fuel of low ignitability. Abstract of paper read before World Power Conference.

ELECTRIC WELDING

Spot, Pressed-Steel Parts. Spot Welding for Pressed Steel Parts, R. Trautschold. Forging—Stamping—Heat Treating, vol. 10, no. 7, July 1924, pp. 265–266. Discusses reasons for employing a.c. supply, contact points and control of temperature distribution area, preparation of stock for spot welding, deep depression welding, and seam welding. Is a practical and highly efficient method of joining light metal parts.

EMPLOYEES' REPRESENTATION

Works Councils. Shop Councils Develop Practical Co-operation. Ry. Age, vol. 77, no. 4, July 26, 1924, pp. 153–155, 1 fig. Particulars of plan of Union Pacific System which meets with approval of officers and men alike.

EVAPORATORS

Types. An Economic Study of Evaporators, T. Fuwa. Chem. & Met. Eng., vol. 31, no. 5, Aug. 4, 1924, pp. 185–188, 2 figs. Cost of installation and operation of five general classes of evaporators and discussion of variable factors.

HAMMERS

Drop. A Remarkable Drop Hammer and Its Work. Engineer, vol. 138, no. 3577, July 18, 1924, pp. 86–87, 4 figs. partly on p. 76. Describes drop hammer designed and made by Brett's Patent Lifter Co., Ltd., Coventry, Eng., for Powell-Brett, Ltd., of Midland Works, Coventry, by whom it is being used, among other things, for direct stamping of railway car wheels. Falling weight weighs 20 tons.

HYDROELECTRIC PLANTS

Automatic. A 7,300-Kva. Automatic Hydro Station. Elec. World, vol. 83, no. 26, and vol. 84, no. 3, June 28 and July 19, 1924, pp. 1319–1322 and 111–114, 10 figs. Sprite Creek development of Adirondack Power & Light Co. is fully self-operating; design details and method of protection of largest automatic installation; hydroelectric features of development; design details of dam, gates, penstocks and intakes; cost of station and hydroelectric works in graphic form.

INTERNAL-COMBUSTION ENGINES

Hot-Bulb and High-Compression. Hot-Bulb and High Compression Engines in Sweden, G. Dellner. Engineering, vol. 118, no. 3055, July 18, 1924, p. 105. Discusses hot-bulb engines and recent improvements, including new methods of starting, application of ball bearings in main bearings. Ellwe and Polar high compression engines and their operation. Abstract of paper read before World Power Conference.

LOCOMOTIVES

Repairing. Rebuilding Narrow-Gage Locomotives, H. Campbell. Am. Mach., vol. 61, no. 4, July 24, 1924, pp. 141–143, 10 figs. Details as to machining of small parts used in repairing of these locomotives.

Steam-Turbine. Geared Turbine Condensing Locomotive. Ry. Age, vol. 77, no. 3, July 19, 1924, pp. 107–108, 1 fig. Mechanical, thermal and economic advantages obtained with Reid-MacLeod steam turbine driven locomotive, built by North British Locomotive Co., Ltd., Glasgow, Scotland. Uniform torque gives rapid acceleration.

MILLING

Automatic. Automatic Milling, F. D. Jones. Machy. (N. Y.), vol. 30, no. 12, Aug. 1924, pp. 919–925, 16 figs. Brown & Sharpe method as applied to various operations selected to show how different classes of work are milled on automatically controlled machines.

MOLDING MACHINES

Movable. Movable Molding Machine for Large Work. Iron Age, vol. 114, no. 5, July 31, 1924, pp. 247–249, 4 figs. Describes traveling sand mixer and rammer which handles molding for 12 to 14-ton castings, developed by foundry of Marion Steam Shovel Co., Marion, O.

MOTOR BUSES

Gasoline-Electric. Gas-Electric Bus Proves Its Worth in 10,000 Mile Test. Automotive Industries, vol. 51, no. 4, July 24, 1924, pp. 195–197, 4 figs. Describes gas-electric bus with Arendt-Morton system of control and propulsion, built by Gen. Elec. Co. and Atlas Truck Corp. and in service on a cross-town line in New York City. Small engine in conjunction with electric power furnishes rapid acceleration and consistent service. Carries 35 to 45 passengers.

MOTOR TRUCKS

Kelly-Springfield. Standardization of Bolt and Bushing Sizes Feature of Kelly-Springfield Line. Automotive Industries, vol. 51, no. 3, July 17, 1924, pp. 146–147, 1 fig. Manufacturing cost reduced and production speed increased by use of similar dimensions wherever possible. Two new models announced. Only one set of right and left panels in design.

OXY-ACETYLENE CUTTING

Cutting Machines. The Godfrey Oxygen Jet Cutting Machine. Engineering, vol. 118, no. 3056, July 25, 1924, pp. 124–125, 11 figs. partly on pp. 123 and 134. Describes oxygen jet cutting machine designed by Alfred Godfrey of Godfrey Eng. Wks., London, for purpose of combining cutting with precision and working with any type of template.

RAILWAY MANAGEMENT

Accounting. Railway Accounting. Ry. Age, vol. 77, no. 3, July 19, 1924, pp. 113–121. Abstracts of papers and reports presented at 36th annual meeting of Railway Accounting Officers Assn., held at San Francisco, Cal., dealing with efficient accounting, expense classification, statistics, and general, freight, passenger, and disbursement accounts.

RAILWAY MOTOR CARS

Gasoline. Motor Car Service on Heavy Grade Road, J. C. Ower. Ry. Age, vol. 77, no. 5, Aug. 2, 1924, pp. 195–196, 3 figs. Change from steam to gasoline propelled equipment has reduced cost of operation.

REFRIGERATING MACHINES

Compression. The Advent of the Compound Compression Refrigerating System, L. J. Sforzini. Power, vol. 60, no. 5, July 29, 1924, pp. 172–174, 4 figs. Describes one of the latest arrangements of compound compression system of refrigeration; shell-and-tube equipment employed for intercooler, gas precooler, condensers and brine coolers, all this apparatus proper being without a single gasketed joint. Notes on four other methods of compound compression. Condensing operation. Steam consumption with different pressures.

ROLLING MILLS

Billet. New Inland Merchant and Billet Mills, G. L. Lacher. Iron Age, vol. 114, no. 6, Aug. 7, 1924, pp. 303–307, 6 figs. Bar mill stands connected with single lineshaft; Kraemer set drive largest yet built; hot bed will take billet from complete ingot, Inland Steel Co., Indiana Harbor, Ind.

ROLLS

Forged-Steel. Hardened and Ground Forged Steel Rolls, J. R. Adams. Forging—Stamping—Heat Treating, vol. 10, no. 7, July 1924, pp. 255–260, 10 figs. Discusses composition, melting and forging, annealing, machining, hardening, grinding, and use of rolls. Forged-steel rolls possess advantages over chilled-iron rolls of greater hardness, more homogeneous surface, greater strength and longer life. Paper read before Am. Iron & Steel Inst.

STEAM POWER PLANTS

High-Pressure. Layout and Operation of 1200-lb. Steam Plant. Power Plant Eng., vol. 28, no. 15, Aug. 1, 1924, pp. 805–806, 2 figs. Particulars of high-pressure power plant installed at Weymouth power station of Edison Elec. Illuminating Co. of Boston. Steam is initially raised to 1200 lb. and 700 deg. fahr. and used in a 3150-kw. turbine which operates with a 350-lb. back pressure.

STEAM TURBINES

Brush-Ljungström. 5,000-Kw. Brush-Ljungström Turbine at the British Empire Exhibition. Engineering, vol. 118, no. 3054, July 11, 1924, p. 71, 4 figs. Particulars of 5000-kw. machine exhibited by Brush Elec. Eng. Co., Ltd., Loughborough, and notes on its advantages.

High-Pressure. Steam Turbines for High Pressures, C. F. Stork. Engineering, vol. 118, no. 3054, July 11, 1924, pp. 69–70, 1 fig. Details of design and construction of high pressure steam turbine made by Erste Brünner Maschinenfabrik on principle that heat consumption can be improved mainly by increasing heat drop in area of high pressure and by building very economical turbine for this area. Abstract of paper read before World Power Conference.

SUPERPOWER

Northeastern United States Survey. Northeast Power in 1930. Elec. Wld., vol. 84, no. 5, Aug. 2, 1924, pp. 205–207, 4 figs. Estimated power demand in 1930, committee advocates large steam stations and development of water power.